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**Benthic marine algal vegetation along the coasts
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to the vertical distribution***

Iemasa YAMADA**

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I. Introduction

The morphology and taxonomy of subtidal benthic marine algae in deep water has been studied for about a century with materials dredged or cast ashore, while the subtidal vegetation has been observed insufficiently owing to the technical difficulties. Since GISLEN (1930), several investigations on the subtidal vegetation using hard hat diving methods or with special investigating apparatus have been carried out (KITCHING *et al.*, 1934; KITCHING, 1937; WALKER, 1947; WAERN, 1952; BURROWS, 1958; JORDE and KLVESTAD, 1963). Scuba techniques were first employed for an ecological study of marine organisms by DRACH (1948), and then by FORSTER (1954, 1955, 1958) and ALEEM (1956). Since about 1960, much valuable information on subtidal marine algae has been obtained by the direct observation with Scuba in several places in the world. Gilmartin (1960) carried out ecological observations of marine algae on a coral reef, KAIN (1960, 1962) studied the subtidal vegetation and ecology of *Laminaria*, NEUSHUL (1961, 1965, 1967) studied the subtidal vegetation and ecology of kelp bed communities. MACLEAN (1962), LAMB and ZIMMERMANN (1964), JORDE (1966), EDELSTEIN *et al.* (1969), and LÜNING (1970) reported on subtidal vegetation or flora, and SVENDSEN and KAIN (1971) studied the taxonomy of *Laminaria* by observations on plants in the field.

In Japan, YOSHIDA (1961), YOSHIDA *et al.* (1963) investigated a *Sargassum* community in Kyushu district by skin diving. YOSHIDA (1973) also studied the subtidal marine algal vegetation at Matsushima Bay, northern Honshu. KIDA (1964, 1965, 1974), TANAKA (1967), TANAKA and ITONO (1969 a, b) reported the marine algal vegetation at certain places in the southern Japan. From Hokkaido, I. YAMADA, (1966) recorded the vertical distribution of certain species at Yakishiri Island, and he (1972) reported preliminarily on the marine algal vegetation and its vertical distribution from Shakotan Peninsula.

On the other hand, many important works on the ecology or phytosociology of intertidal marine algae have been reported from various coastal waters of the world. In Japan, ecological observations have been made by SEGAWA (1947), UJIKE (1956), MATSUURA (1958), KATADA (1952), TANIGUTI (1961), and HAYASHIDA and SAKURAI (1969). From the coasts of Hokkaido, TANIGUTI (1961) observed intertidal marine algae from the phytosociological point of view at several localities. Analytical studies on marine algal communities were made by FUNANO and HASEGAWA (1964), SAITO and ATOBE (1970), SAITO *et al.* (1971), TORII *et al.* (1972) and ATOBE and SAITO (1974).

In adjacent regions of the northern Japan, NAGAI (1941) reported intertidal and subtidal vegetation in his floristic study of the Kurile Islands. TOKIDA (1954) described vegetational characteristics of the south Sakhalin in his floristic study. STSCHAPOVA and SELITSKAYA (1957) described the intertidal zonation at Moneron Island of the south Sakhalin. VOZZHINSKAYA (1964) studied the composition and distribution of marine algae on the coast of Sakhalin, in which the vertical ranges of intertidal species were described. VOZZHINSKAYA (1966) also reported the zonation of the benthic marine algae along the continental coasts of Okhotsk Sea. VOZZHINSKAYA and SELITSKAYA (1970) described the marine vegetation on the coast of Shantar Island, west coast of Okhotsk Sea. VOZZHINSKAYA and BLINOVA (1970) reported the distribution and composition of marine algae from the Okhotsk Sea coast of Kamtschatka.

Thus, in the past decade the knowledge on subtidal vegetation has increased, but there has been very little data collected concerning the subtidal vegetation in Japan, especially in Hokkaido.

The marine algae of Hokkaido have been described in many floristic and monographic works. From the west coast, INAGAKI (1933) reported red algae from Oshoro Bay, Y. YAMADA, (1942) listed deep water algae of Matsumae-Kojima, HASEGAWA (1949) reported the flora of Okushiri Island, TOKIDA and MASAKI (1959) made a list of marine algae of Oshoro and its vicinity, FUKUHARA (1959) reported some marine algae from Rebun Island, and KANEKO and NIIHARA (1970) made a list of marine algae of Rishiri Island. From Tsugaru Straits, MORITAKE (1949) studied the flora of Hako-date Bay, YAMAMOTO (1965) recorded nine warm current species on the north coast of the strait. From the Pacific coast, YAMADA and TANAKA (1944 a) made a list of marine algae from Akkeshi Bay, CHIHARA (1972) described marine algae from Hidaka district, and KAWABATA (1959) reported marine algae from Shirikishinai in southern Hokkaido. From the Okhotsk Sea coast, YAMADA and TANAKA (1944 b) listed the marine algae on Shiretoko

Peninsula, IWAMOTO (1960) studied marine algae at Lake Saroma, and TSUJI and KAKIUCHI (1974) reported several algae from Lake Notoro. However, the taxonomical and ecological information on subtidal marine algae is still insufficient.

The purpose of this investigation is to elucidate the benthic marine algal vegetation along the coasts of Hokkaido, especially to make clear the vertical distribution of marine algae forming distinct belts in the area from the supratidal to a maximum depth of 25 m.

Investigations were carried out at twenty-three stations selected around Hokkaido from 1964 to 1970. Of these, dives were made at twenty-one stations during the summer from 1965 to 1970.

During these dives, investigations in two areas, Shiretoko Peninsula and Nemuro Peninsula, were also carried out as a part of the research on "Marine algae in the cold current region of the northern Japan" organized by Professor M. Kurogi of Hokkaido University, and the investigation in

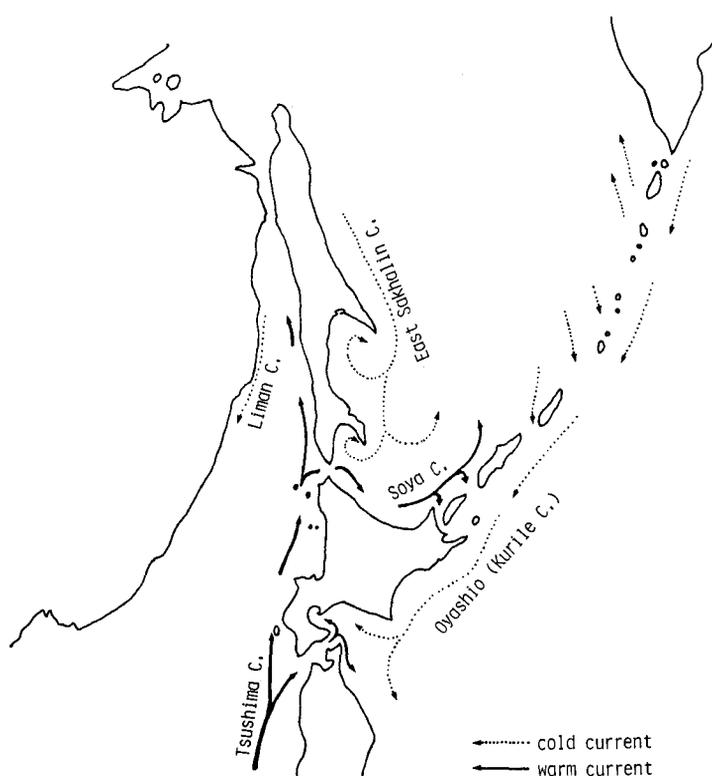


Fig. 1. The current system in the warmer season in the vicinity of Hokkaido (modified after WATANABE, 1964, 1967).

Shakotan Peninsula was a part of a survey organized by the Marine Park Center of Japan.

II. Oceanography

1. Currents

Hokkaido mainland ($41^{\circ}50'N-45^{\circ}30'N$, $139^{\circ}45'E-145^{\circ}46'E$), the northernmost major Japanese island, is influenced by three oceanic currents, the cold Kurile Current (Oyashio), the warm Tsushima Current and the East Sakhalin Current (Figs. 1, 2). The Oyashio washes the Pacific coast from Nosappumisaki on Nemuro Peninsula to Hidaka district and then it mixes with the warm Tsugaru Current, a branch of the Tsushima Current, in Uchiura Bay. The east side of Tsugaru Straits and the north Pacific coast of Tohoku district of Honshu are influenced by the Oyashio especially in the winter season.

On the contrary, the warm Tsushima current, a large branch of the

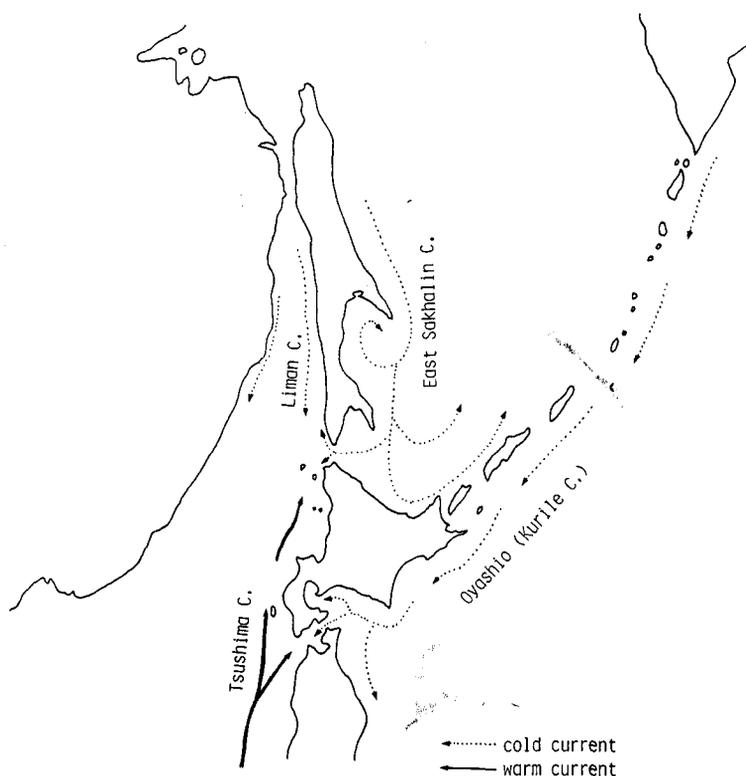


Fig. 2. The current system in the cooler season in the vicinity of Hokkaido (modified after WATANABE, 1964, 1967).

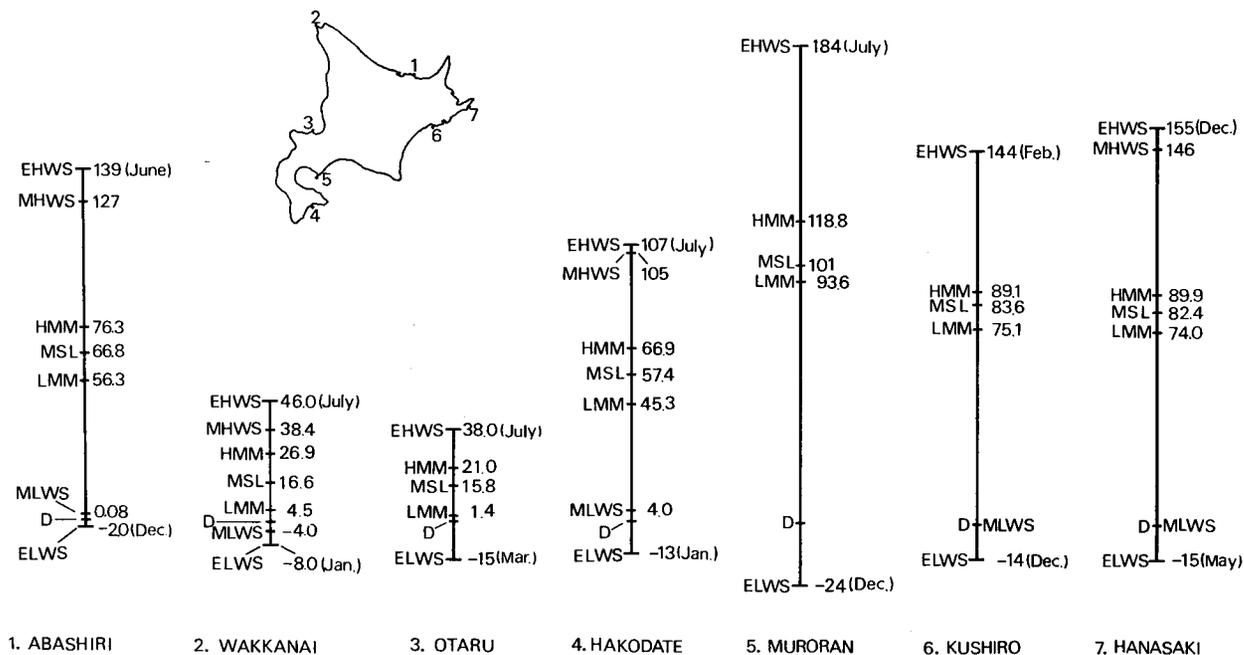


Fig. 3. Tidal ranges and levels at seven localities in Hokkaido, figured from the Tide Table of the year 1967 by Japan Meteorological Agency. The abbreviations are defined as follows: EHWS, Extreme High Water Spring Tide; ELWS, Extreme Low Water Spring Tide; MHWS, Mean High Water Spring Tide; MLWS, Mean Low Water Spring Tide; HMM, High Monthly Mean Tide Level; LMM, Low Monthly Mean Tide Level; MSL, Mean Tide Level (1961-1966); D, The level at 0 cm in the Tide Table.

TABLE 1. The monthly mean of surface seawater temperatures (C) recorded at fifteen stations in Hokkaido (after FUKUHARA, 1968, and data recorded at Oshoro Bay by the Marine Biological Station and at Muroran by the Institute of Algological Research of Hokkaido University, and the data at Kushiro in "Hokkaido Engan Suiroshi, 1966" by Maritime Safety Agency)

Locality	Month	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Av.	Data
	Matsumae		5.7	5.0	5.9	8.2	11.3	15.2	19.6	23.5	21.6	16.8	12.0	7.9	12.7
Suttsu		5.3	4.5	5.2	7.6	10.7	14.8	19.3	22.4	20.9	16.6	11.6	7.5	12.2	"
Kamui-misaki		5.6	4.9	5.1	7.1	10.3	14.2	18.9	22.0	20.4	16.2	11.8	7.9	12.0	"
Ohoro		4.9	3.8	4.6	5.9	13.5	14.6	17.2	20.6	19.3	16.0	11.9	7.0	11.6	1966
Yakishiri Isl.		3.5	2.9	3.9	6.4	10.4	15.3	19.1	22.2	19.8	15.6	10.1	6.1	11.2	1946 to 65
Soya-misaki		-0.9	-1.3	1.1	5.7	9.7	13.9	17.8	20.8	18.1	12.7	6.5	1.8	8.8	"
Ohmu		-1.1	-1.0	0.4	4.5	9.1	12.8	16.7	19.8	18.3	13.9	7.1	1.4	8.4	"
Nosappu-misaki		-1.2	-1.7	-0.9	2.1	5.7	8.8	12.2	15.8	16.2	13.0	7.8	2.2	6.6	"
Akkeshi		-0.7	-1.3	0.3	4.2	7.4	11.0	15.0	18.0	17.3	13.3	7.6	3.2	7.9	"
Kushiro		0.0	-0.9	-0.2	2.4	5.4	9.0	12.5	17.0	16.4	13.4	8.5	3.6	7.9	1944 to 61
Erimo-misaki		0.2	-0.6	0.7	3.3	5.7	9.3	13.4	16.4	16.5	13.2	8.0	3.3	7.4	1946 to 65
Urakawa		1.5	0.5	1.3	3.6	6.5	10.7	15.8	19.2	18.3	14.8	9.3	5.0	8.8	"
Muroran		4.7	3.6	2.9	4.1	7.2	11.9	15.9	18.8	19.4	15.3	10.6	7.3	10.1	1965
Esan		5.1	3.2	2.7	4.2	7.0	10.3	15.3	18.9	19.0	16.1	12.2	8.4	10.2	1964 to 65
Hakodate		4.4	3.8	4.5	7.3	9.4	12.7	19.0	23.1	21.3	17.2	12.0	7.1	11.8	"

Kuroshio, flows northwards along the Japan Sea coast of Hokkaido and turns to the east from Sôya Straits and flows along the Okhotsk Sea coast of Hokkaido (Sôya Current). The Sôya Current then flows eastwards in the Okhotsk Sea through the offshore region on the north side of the South Kuriles. Some small branches flow southwards into Nemuro Straits and Kunashiri Straits and a small amount of water overflows into the Pacific at an area neighbouring Nosappu-misaki. Furthermore, two other cold currents, the East Sakhalin Current and the Liman Current, flow southwards from the north and prevail in the northern area of Hokkaido including Rebun Island, Rishiri Island and the Okhotsk Sea coast in the winter season. The coasts of Hokkaido, therefore, have very complicated conditions according to the season.

2. Tidal range

The tidal range of the Pacific coast is larger than that of the Japan Sea coast. The latter is only about 50 cm, while the former reaches about 150 to 200 cm (Fig. 3). The monthly mean tidal level during the year from 1962 to 1966 (TIDE Table, 1967) at Wakkanai, Otaru, Hakodate, and Muro-ran are generally high in the summer (June-August) and low in the spring



Fig. 4. Isothermal lines of the surface seawater temperature (C) in the summer season (modified after Hokkaido Fish. Exp. Sta., 1969, 1970).

(March-May), while that at Abashiri on the Okhotsk Sea coast, Kushiro and Hanasaki of eastern Pacific coast are high in the winter (December-February) and low in the spring (HMM and LMM in Fig. 3). At Otaru situated in the middle part of the Japan Sea coast of Hokkaido, the upper limit in the spring, when the mean tidal level becomes the lowest, usually does not exceed the lower limit of the summer high tide since the tidal range is very narrow. The tidal range in a lunar day at Otaru is only about 20 cm. On the Pacific coast and the Okhotsk Sea coast, winter ebb tides occur at night, while on the Japan Sea coast they occur in the daytime.

3. Seawater temperature

According to oceanographic data (Hokkaido Fisheries Experimental Stations, 1969), the maximum surface water temperature is 24°C on the coast of Matsumae district in August, while during the same season in the eastern Pacific it reaches only 12~13°C except in the inner areas of bays. In the winter the surface water temperature falls to 4~6°C in the southern area



Fig. 5. Isothermal lines of the surface seawater temperature (C) in the winter season (modified after Hokkaido Fish Exp. Sta., 1969, 1970). The area indicated by shading is the area affected by drift ice (modified after WATANABE, 1969).

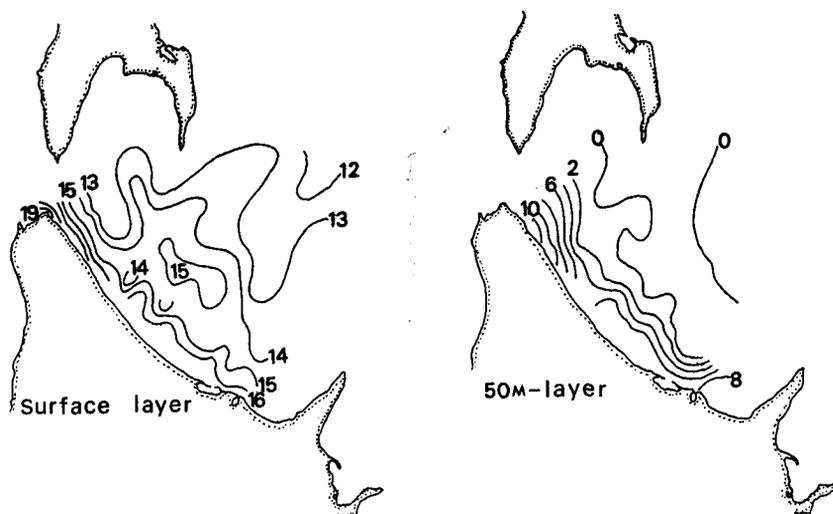


Fig. 6. Isothermal lines of the surface seawater temperature (°C) and 50 m-layer temperature in the middle of August on the Okhotsk Sea coast, showing the cold water mass at a laer 50 m depth (after Hokkaido Fish. Exp. Sta., 1969).

and $-1.5\sim 0^{\circ}\text{C}$ on the northern and eastern coasts (Table 1 and Figs. 4, 5). On the Okhotsk Sea coast and on the eastern coast of Hokkaido, drift ice comes down from the northern area of the Okhotsk Sea in January or February (Fig. 5), and the coastal areas are densely covered with ice-blocks.

In the subtidal zone, water temperatures around Hokkaido reported during the summer at the 50 m-layer are mostly $8\sim 10^{\circ}\text{C}$ lower than those at surface, but in the offshore waters of Okhotsk Sea coast, the temperatures fall abruptly between the 20 and 30 m-layers (Fig. 6). This cold water mass may be related to upwelling of cold water in the area of the southernmost part of Sakhalin according to MIYABE (1928) and TOKIDA (1954).

4. Air temperature

Monthly and yearly average air temperatures reported from twelve coastal stations are shown in Table 2. The maximum and minimum air temperatures ($^{\circ}\text{C}$) recorded in 1968 by three coastal stations are given below.

	Max.	Min.
Japan Sea coast, Esashi	28.7 (July.)	-6.1 (Feb.)
Okhotsk Sea coast, Monbetsu	25.8 (July.)	-12.9 (Feb.)
Pacific coast, Urakawa	23.9 (Aug.)	-7.3 (Jan.)

Thus, the air temperature in a year changes within a range of $30\sim 40^{\circ}\text{C}$.

TABLE 2. The monthly mean of air temperatures (C) recorded at twelve stations in Hokkaido (after the data in "Hokkaido Engan Suiroshi")

Locality	Month													Av.	Data
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.			
Shakotan-misaki	-4.1	-2.7	-0.1	6.2	10.9	13.6	18.1	20.4	17.7	12.3	5.1	-1.1	8.0	1956 to 60	
Otaru	-4.3	-3.3	-0.1	6.3	11.5	14.9	19.6	21.4	17.5	11.5	4.1	-1.0	8.2	1951 to 60	
Yakishiri Isl.	-4.9	-3.8	-0.5	5.2	9.5	13.7	18.2	20.5	17.9	12.2	4.2	-1.0	7.6	"	
Wakkanai	-5.9	-5.6	-1.8	4.0	8.4	12.2	16.7	19.6	16.6	10.7	3.0	-2.9	6.2	1941 to 60	
Kitami-Esashi	-7.4	-6.8	-2.9	4.1	8.7	11.2	16.0	18.3	15.8	9.6	1.8	-3.4	5.4	1951 to 60	
Abashiri	-6.7	-7.0	-2.9	3.6	8.7	12.4	17.0	19.5	15.8	10.1	3.1	-3.2	5.9	1931 to 60	
Nemuro	-4.8	-5.6	-2.2	2.8	6.8	10.0	14.3	17.5	15.5	10.8	4.7	-1.3	5.7	"	
Kushiro	-6.9	-6.4	-2.2	3.0	7.1	10.9	15.4	18.1	15.2	9.6	3.2	-2.9	5.3	"	
Erimo-misaki	-2.9	-2.8	-0.6	3.6	7.1	10.3	14.7	17.7	16.3	12.3	6.0	0.8	6.9	1951 to 60	
Muroran	-2.7	-2.5	0.3	5.3	10.0	13.7	18.5	21.2	15.1	12.6	5.8	0.0	8.4	1931 to 60	
Esan	-2.4	-1.7	1.0	6.5	10.9	13.6	18.1	20.9	18.2	13.1	6.1	0.9	8.8	1951 to 60	
Hakodate	-4.1	-3.6	0.0	6.1	11.0	14.8	19.4	21.6	17.2	11.3	4.6	-1.3	8.1	1941 to 60	

5. Water transparency

Water transparency is usually high in the warm current and low in the cold current area. During this work, a maximum of 24 m was recorded near shore on Shakotan Peninsula and a minimum of 4 m at Akkeshi. Data recorded during the course of this work and other data reported in several oceanographic investigations (FUKUTOMI *et al.*, 1950; Oceanographic data of Hokkaido Exp. Sta., 1966-1970) are shown in Fig. 7.

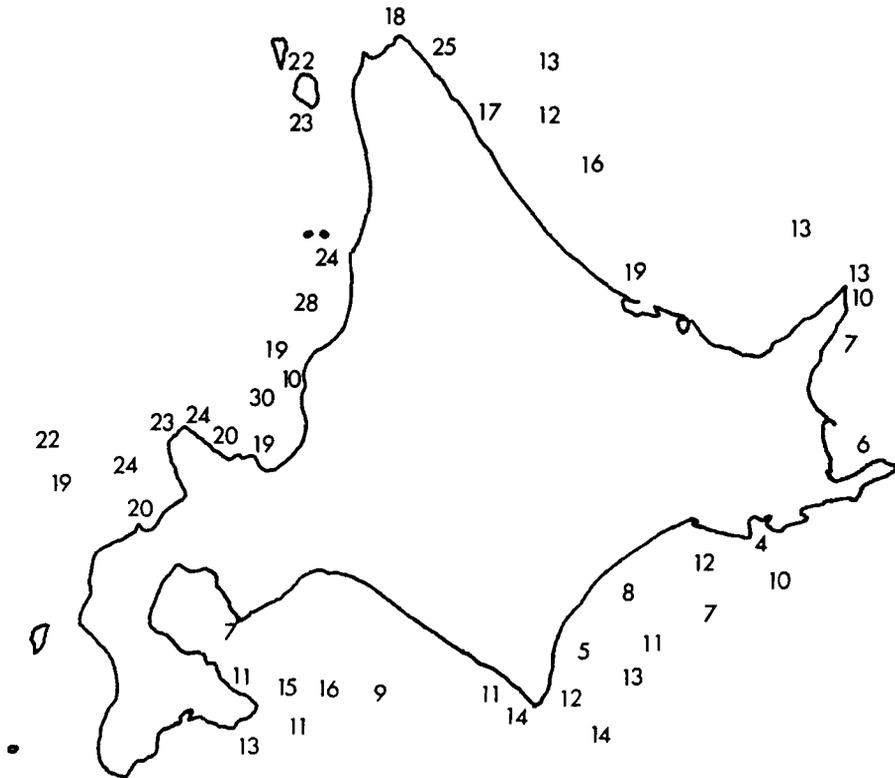


Fig. 7. Water transparency in meters around Hokkaido, based on the data recorded with a Secchi's disc in this study and from the oceanographic data by Hokkaido Fish. Exp. Sta., 1967-1970.

III. Methods

The investigations were carried out at twenty-three localities shown in Fig. 8. Of these, the vegetations at Utoro on the Okhotsk Sea coast and at Erimo-maisaki on the Pacific coast were observed only in the intertidal zone. Subtidal investigations were carried out qualitatively by direct ob-

servation with diving apparatus. The investigator moved along a nylon rope (transect line) marked off in centimeters set on the bottom recording the species encountered. Plants belonging to the crustose Corallinaceae were

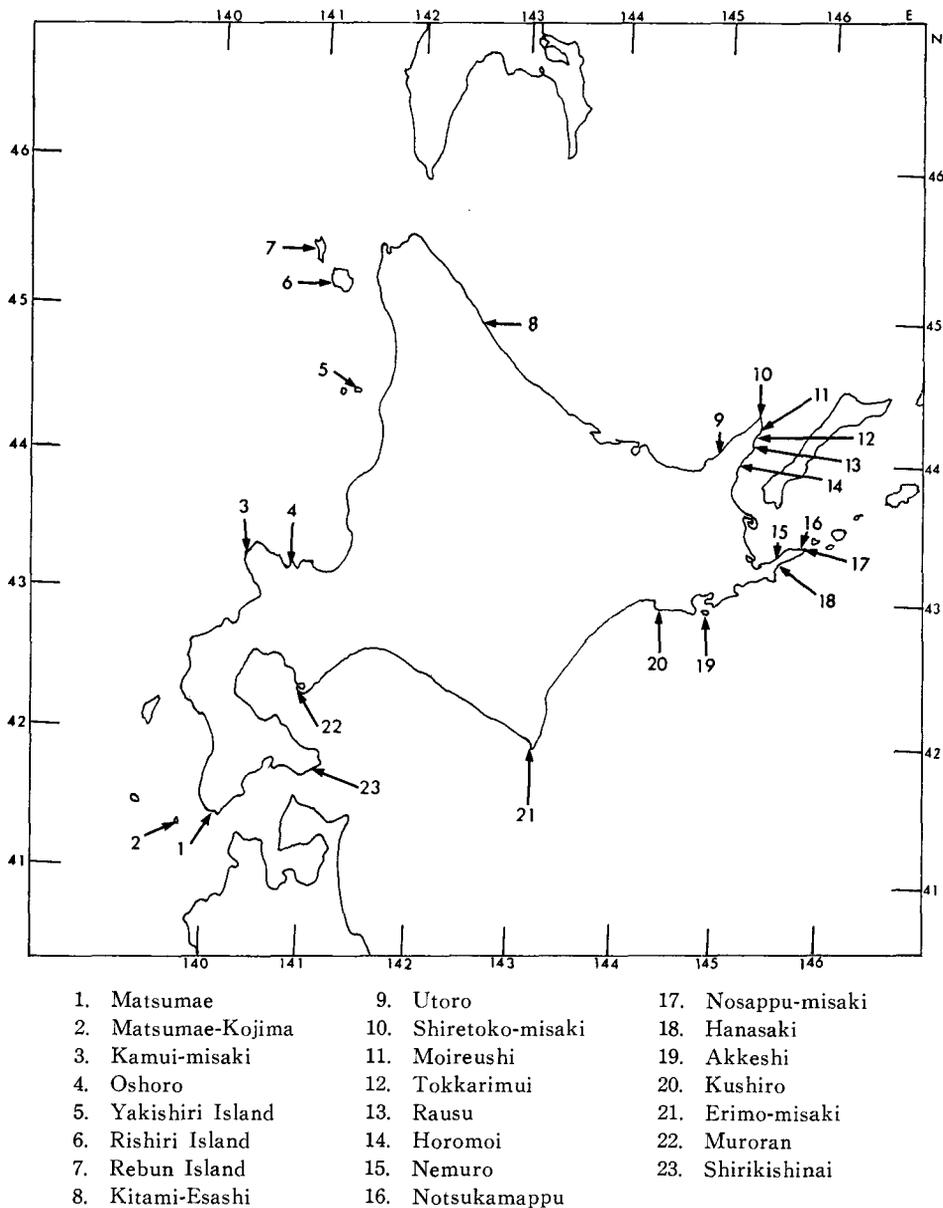


Fig. 8. Localities investigated.

omitted. When the subtidal slope was long and gentle, an investigator dived from a boat in areas of certain depths, usually at 0~5, 10, 15, 20, 25 meters. A quadrat (50×50 cm) was employed when a quantitative observation was needed. Depths in this paper correspond to the depth below ELWS (0 cm in the figures) in Tide Tables. Transparency was measured with a Secchi's disc. Specimens collected are preserved in the herbarium of the Department of Botany, Faculty of Science, Hokkaido University.

IV. Observations

Japan Sea Coast

1. Matsumae

The coastline of Matsumae district is located in the south-westernmost area of Hokkaido and is situated at the western entrance to the Tsugaru Straits. The warm Tsushima Current washes the coast directly and the surface sea-water temperature reaches 24~25°C at the end of August. Matsumae district, therefore, is the most temperate area in Hokkaido.

Diving work was carried out on June 13, 1968 and intertidal observations were done on September 9, 1966 and April 26, 1967. The station selected was on a rocky slope at Benten-jima (41°25'N, 140°05'E) near the Matsumae fishing port. The area investigated is an exposed rocky slope facing almost directly south and descending steeply from the intertidal to a depth of 10 m. Below 10 m the bottom consists of pebbles, large irregular rocks, and boulders and declines gently offshore.

The profile of the vertical distribution on June 13, 1968 is shown in Fig. 9, A. The vertical range of the intertidal vegetational zone is about 80 cm. The three major intertidal belts were recognized essentially by the occurrence of *Gloiopeltis furcata* in the upper, barnacles in the middle, and *Hizikia fusiformis* in the lower. *Gloiopeltis furcata* densely occupied the region between 60 and 80 cm above ELWS. The mid intertidal zone was dominated by barnacles with only a scattered amount of *Gloiopeltis furcata* and *Corallina pilulifera*. In the lower portion of this *Gloiopeltis* belt a small amount of *Blidingia minima* occurred. The lower intertidal in this area was characterized by a remarkable belt of *Hizikia fusiformis*, which mostly dominated the region between 35 cm above ELWS and ELWS. The lower limit of this belt approximately corresponds to ELWS in this area. *Hizikia fusiformis* is one of the most representative species in the southernmost coast of Hokkaido and is regarded as a species indicating the intensity of the warm current.

Below ELWS, two distinct belts formed by *Sargassum sagamianum*

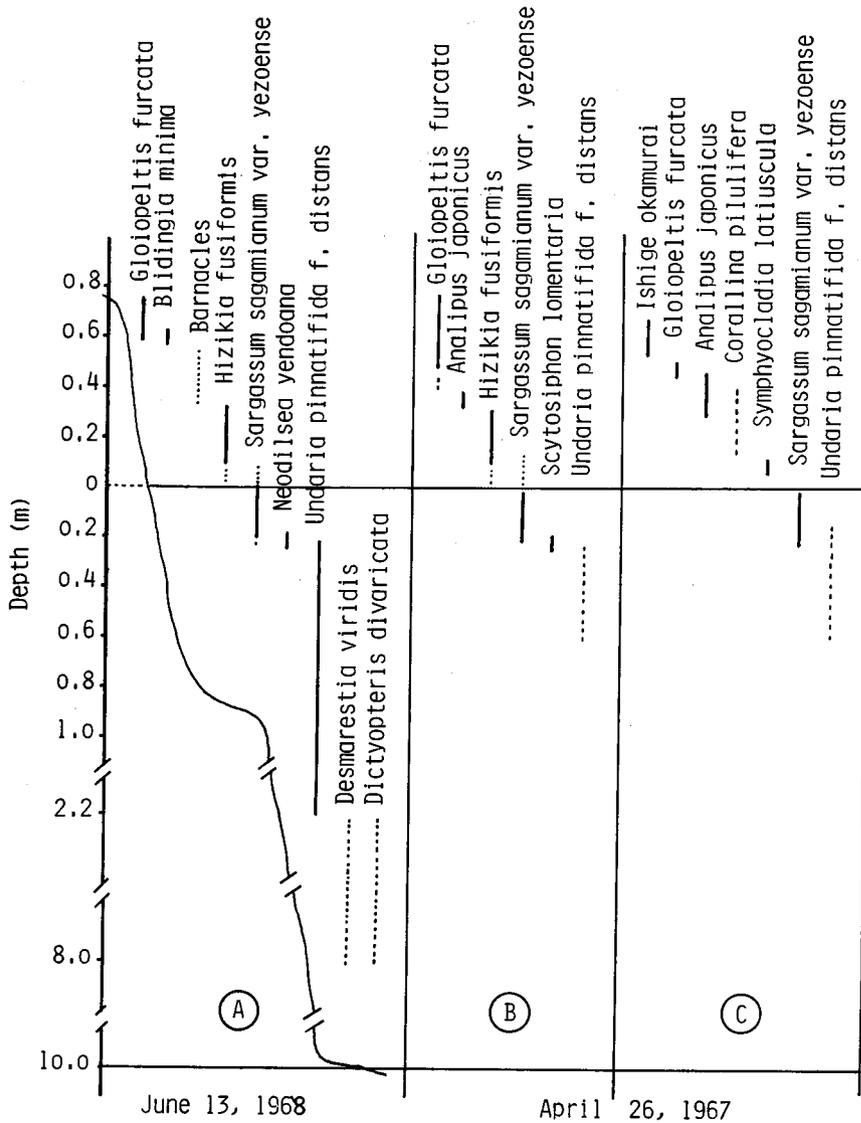


Fig. 9. Matsumae (Loc. 1). Profile of the vertical distribution at exposed area in June (A), in April (B), and the semi-exposed rock in April (C) (April 26, 1967; June 13, 1968).

var. *yezoense* and *Undaria pinnatifida* f. *distans* were observed. The *Sargassum* belt was found in the lower intertidal and the upper part of subtidal zone. In another place, the *Sargassum* community extended down to a depth of half a meter or more, however, the main habitat of the population

occurred in a very narrow vertical range near ELWS. Below the *Sargassum* belt, an indistinct zone of *Neodilsea yendoana* was recognized. However, this species also observed just below the *Hizikia* belt in April, 1967. Therefore, it is thought that this species can not be regarded as a species forming an essential zone in this area. The main zone below the *Sargassum* belt was formed by *Undaria pinnatifida* f. *distans*, which is one of the subtidal marine algae peculiar to the warm current. The *Undaria* belt was found in a range between 20 or 40 cm and about 2 m below ELWS and the main habitat was found on a relatively gently declining bottom. In the area below the *Undaria* belt distinct zonation was not found. Small amounts of *Desmarestia viridis*, *Dictyopteris divaricata*, and some plants belonging to the crustose coralline algae occurred sparsely down to a depth of 8 m, but some sea urchins occurred there. At a depth of 10 m, the bottom became nearly flat with many pebbles, and plants were scarce.

The intertidal zonation on April 26, 1967 was similar to that described above (Fig. 9, B). The tidal level at that time was lower because of the spring tide, and the actual seawater level corresponded to ELWS in this area (-9 cm in the Tide Table). Therefore the actual seawater level was just below the *Hizikia* belt. Additionally, *Gloiopeltis furcata* covered the whole *Balanus* population mentioned before, and *Analipus japonicus* occurred between the *Gloiopeltis* belt and the *Hizikia* belt. Furthermore, a very distinct belt of *Ishige okamurai* could be seen on the upper portion of a rock near the station (Fig. 9, C). *Ishige okamurai* usually forms a remarkable belt in the mid intertidal zone on the coasts of middle and southern Honshu, but this phenomenon is uncommon in Hokkaido. This occurs only on the coast facing Tsugaru Straits. *Porphyra yezoensis* was abundant in April as an epiphyte on *Ishige*. *Scytosiphon lomentaria*, *Corallina pilulifera*, *Chondria crassicaulis*, *Laurencia* sp., *Rhodochorton* sp., and *Erythrotrichia japonica* epiphytic on *Sargassum sagamianum* var. *yezoense* were also collected. In autumn, September 9, 1966, *Champia parvula*, *Lomentaria hakodatensis*, *Gracilaria verrucosa*, *Rhodomela larix*, *Gymnogongrus flabelliformis*, *Dictyota dichotoma*, *Codium fragile*, and *Bryopsis hypnoides* were collected near the station.

2. Matsumae-Kojima

Matsumae-Kojima, an uninhabited islet, is located about 24 km west off the coast of Matsumae and has a coastline of 6 km. The islet is affected by the warm Tsushima Current throughout the year and has been known as a place where many warm current species grow that are usually found in Honshu district, such as *Ecklonia stolonifera* (YAMADA, 1942).

The investigation was carried out on June 14, 1968 on the east coast near the small harbor. The area observed is an exposed rocky cliff descending vertically to a depth of 8 m. From there the slope descends to a depth of 12 m.

The profile of the vertical distribution on June 14, 1968 is shown in Fig. 10.

The intertidal vegetation in the area is very poor. Only small amounts of *Gloiopeltis furcata* and *Corallina pilulifera*, and *Balanus* sp. were found on the vertical rock face and on *Mytilus* sp. which attached firmly to the

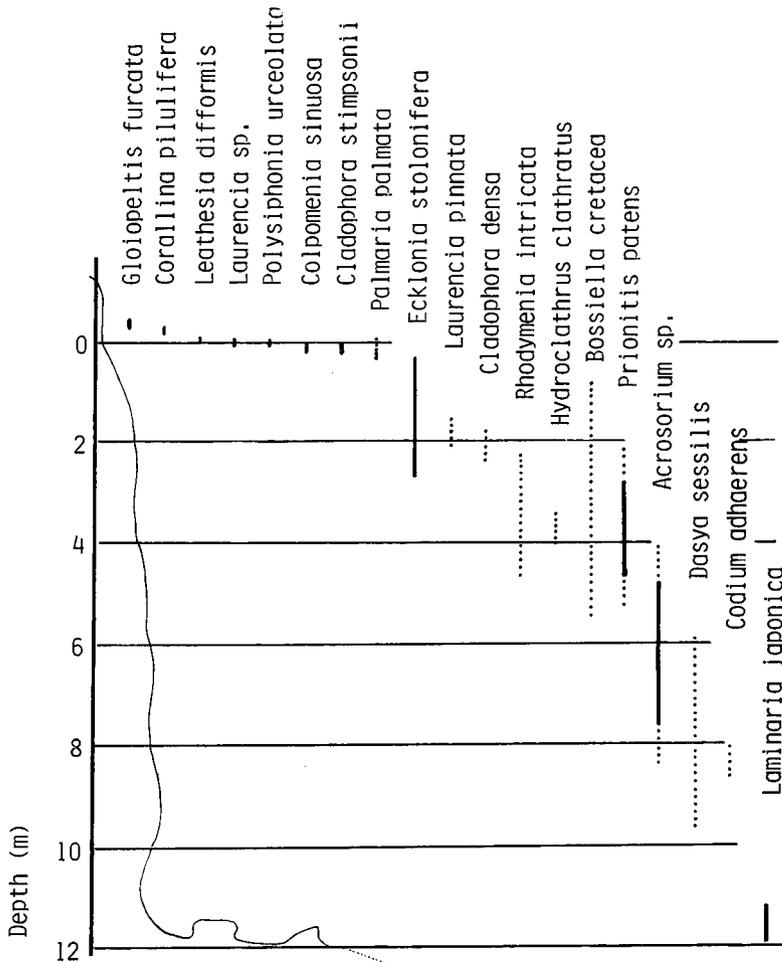


Fig. 10. Matsumae-Kojima (Loc. 2). Profile of the vertical distribution in the subtidal zone (June 14, 1968).

rock in the lower intertidal zone. The most characteristic feature in this area was the occurrence of *Ecklonia stolonifera*. It dominated the area between 50 cm and about 3 m below ELWS. The area between ELWS and the upper limit of *Ecklonia* belt was occupied by *Corallina pilulifera*, *Leathesia difformis*, *Laurencia* sp., *Polysiphonia urceolata*, *Colpomenia sinuosa*, *Cladophora stimpsonii*, and *Palmaria palmata*. But no distinct belt formation was recognizable. Below the *Ecklonia* belt, *Prionitis patens* occurred relatively abundantly between 3 and 5 m below ELWS. However, this species did not form a distinct belt, but was scattered in small groups. Another species, *Acrosorium* sp. (*A. flabellatum*?) abundantly covered the rock or the coralline algae between 5 and 8 m below ELWS. At 12 m below ELWS, a large community of *Laminaria japonica* were conspicuous. This plant was about 60~70 cm in height. Most of the upper portion of the thallus was light in color, and the uppermost portion was worn away. At this time these plant seemed to be one year of age. In addition to the species mentioned above, *Bossiella cretacea*, *Rhodymenia intricata*, *Dasya sessilis*, *Laurencia pinnata*, *Griffithsia japonica*, *Monospora tenuis*, *Sphaerotrachia divaricata*, *Hydroclathrus clathratus*, *Codium adharens* and *Cladophora densa* were collected. Thus, it may be said that the subtidal zonation of this area is delineated by the presence of *Ecklonia stolonifera*, *Prionitis patens*, *Acrosorium* sp., and *Laminaria japonica* respectively, although sometimes the zonal boundaries were indistinct.

3. Kamui-Misaki

Shakotan Peninsula protrudes westward into the Japan Sea from the middle part of western Hokkaido. The coastline of the peninsula consists of stretches of rocky shore, cliffs or ledges, and boulders or sandy beach. This coast is affected by the warm Tsushima Current. The seawater temperature varies between 22°C in summer and 3°C in winter. The water transparency is very high. The maximum water transparency observed during the investigation was 24 m. The tidal range is very narrow, being similar to that at Otaru.

Kamui-misaki (43°20'N., 140°21'E.) is the tip of Shakotan Peninsula. The many rocks emerging from the water form a jagged line off the short terrace under the steep cliff of the shore. The investigation was carried out at two stations on August 6, 1970. Station 1 is an exposed rocky cliff near the extreme tip of the peninsula where the vertical distance between the intertidal zone and the flat bottom is 9 m. Station 2 is a semi-exposed place about 1 km east of Station 1. The edge of the shore declines steeply to 3 m and then descends gradually to the irregularly flattened bottom at

a depth of 7 m, where is about 100 m offshore.

The profile of the vertical distribution on August 6, 1970 is shown in Fig. 11.

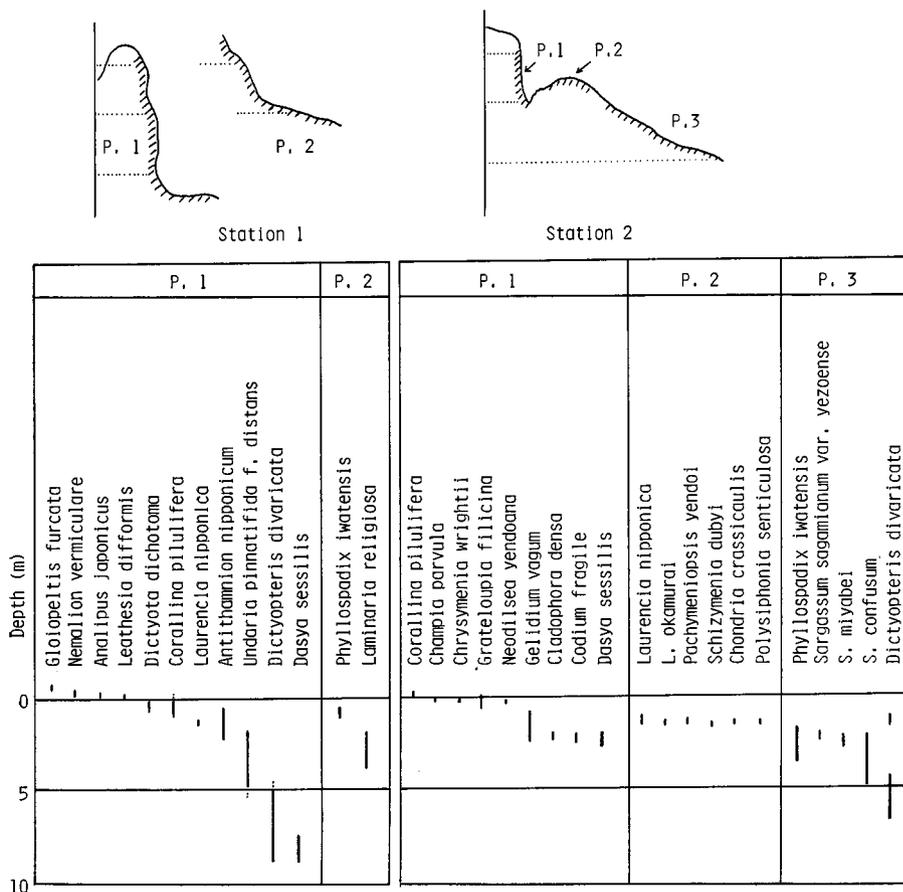


Fig. 11. Kamui-misaki (Loc. 3). Profile of the vertical distribution at the offshore rock (Station 1, P. 1) and near the shore (Station 1, P. 2) at the head of the cape, and at another subtidal zone near the shore (Station 2, P. 1, 2, 3) (August 6, 1970).

Station 1: The vegetation in this area was very poor. In the intertidal zone *Gloiopeltis furcata*, *Nemalion vermiculare*, *Analipus japonicus* (basal portion only), *Leathesia difformis*, *Dictyota dichotoma* and *Corallina pilulifera* occurred sparsely. Just below ELWS, *Mytilus edulis* formed a dense population to a depth of 30 cm, or to 2.5 m in places, the shells of which were covered by *Corallina pilulifera*, *Dictyota dichotoma* and *Antithamnion*

nipponicum. *A. nipponicum* attached to the shaded side of the shell or below overhanging rock. Below the *Mytilus* belt, *Corallina pilulifera* formed a distinct belt down to 60 cm below ELWS. On gentle slopes at a depth of about 1.5 m, *Laurencia nipponica* occurred abundantly. The zone between 1.5 m and about 5 m was dominated by *Undaria pinnatifida* f. *distans*, the main belt of which was found at about 2 m to 2.5 m below ELWS. In the area between 5 m and 9 m, *Dictyopteris divaricata*, small amounts of *Dasya sessilis*, and plants belonging to the crustose Corallinaceae were sparse. In the subtidal zone near Station 1, *Laminaria religiosa* formed tufts on the tops of large boulders and protruding bedrock between about 2 m and 4 m below ELWS, and *Phyllospadix iwatensis* occurred abundantly on the flat rocks between 50 cm and 1.0 m depth where sand accumulated.

Station 2: *Codium fragile*, *Cladophora densa*, *Gelidium vagum*, *Champia parvula*, *Dasya sessilis*, *Glateloupia filicina* and *Corallina pilulifera* were found on the vertical rock down to a depth of 3 m just below the rim of the rocky terrace along the shore. In shaded small crevices at 30 to 50 cm depth near the shore, *Neodilsea yendoana* and *Chrysomenia wrightii* were found. *Laurencia nipponica*, *Pachymeniopsis yendoi*, *Schizymenia dubyi*, *Chondria crassicaulis*, and *Polysiphonia senticulosa* were found on the flat rock near the shore at 1.5 m depth.

On the uneven bottom or on small boulders between a depth of 2 and 5 m, where is about 25 m to 45 m offshore, a *Sargassum* community occurred. In the community, *S. confusum* grew everywhere, and *S. sagamianum* var. *yezoense* formed a dense community at shallow and restricted areas from 2 to 2.5 m depth. A small amount of *S. miyabei* occurred sparsely among the *S. confusum*. *Phyllospadix iwatensis* also occurred on flat areas and in shallow depressions on the rock surfaces in this area.

Below the *Sargassum* community, vegetation was poor and very similar to that found at Station 1.

Other stations: The vegetation at three other stations on Shakotan Peninsula, Shakotan-misaki, Anama, and Biyano-misaki, was also investigated. The vegetation recorded at these stations was very similar to that found at Kamui-misaki. The subtidal vegetation was characterized by the occurrence of the *Dictyopteris divaricata* community as well as those of *Laminaria religiosa*, *Sargassum confusum* and *S. sagamianum* var. *yezoense*. For example, on a shaded steep slope at Biyano-misaki *D. divaricata* inhabited the entire range between a depth of 1.0 and 13 m. In this region, old plants of *Palmaria palmata* occurred in the lower intertidal or in the uppermost part of subtidal zone, and *Laminaria religiosa* and a small amount of *Chorda*

filum occurred in the deeper zone between 4 and 5 m. *Dictyopteris divaricata* was common also in the lower intertidal zone, and subtidal plants were smaller in height, thinner, and lighter in color than those of the intertidal zone.

4. Oshoro Bay

Oshoro Bay is located about 24 km west of Otaru City. The shore outside the bay is bordered by a narrow ledge under the steep cliffs. The head of the bay is about 800 m from the entrance. The inside of the bay

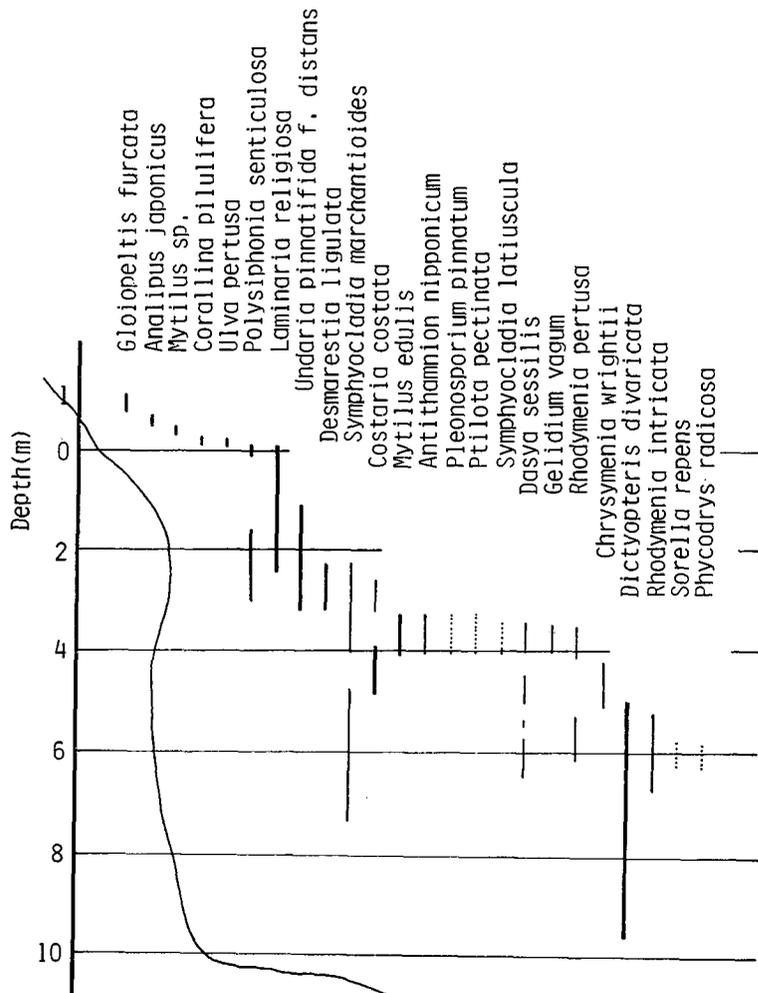


Fig. 12. Oshoro Bay (Loc. 4). Profile of the vertical distribution at exposed place near Kabuto-iwa (July 27, 1966).

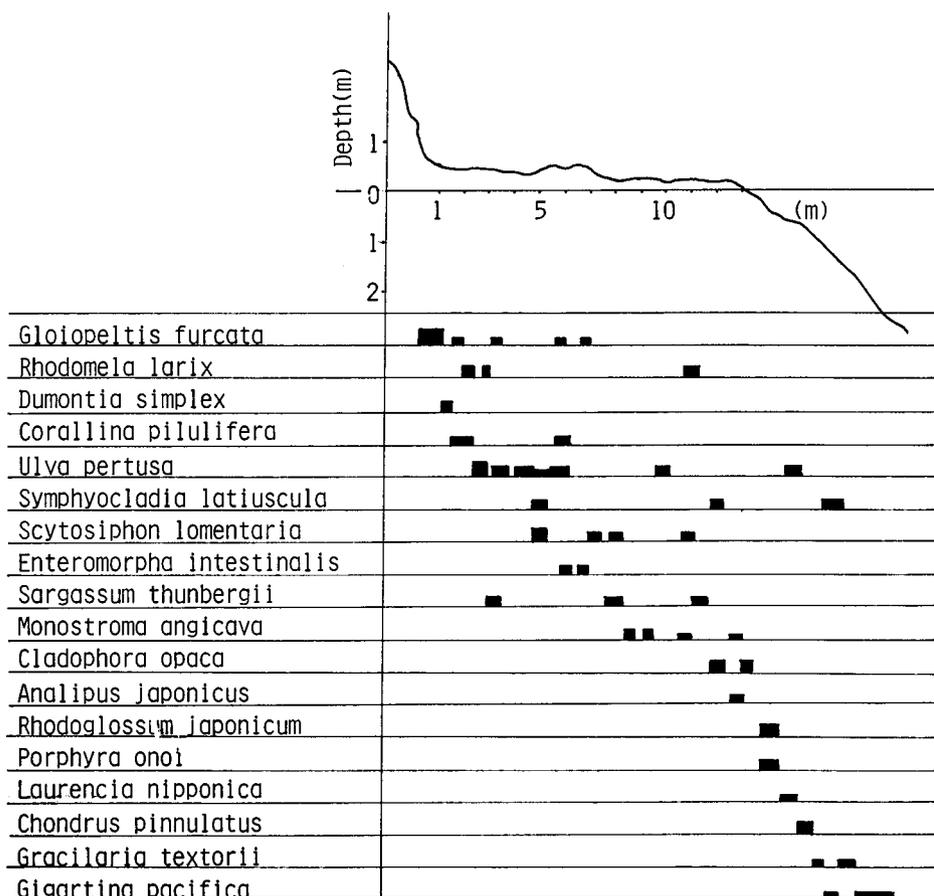


Fig. 13. Oshoro Bay (Loc. 4). Profile of the vegetation at sheltered place near Kabuto-iwa (June 4, 1966).

is bordered by a small ledge and a small sandy beach. The depth is 11 m at the entrance, near Kabuto-iwa, and gradually becomes shallower towards the head of the bay and deeper offshore. The rocky bottom at the entrance changes into sand at a depth of 13 m where is 20 or 25 m offshore. The intertidal zone on this coast is very narrow, as it is in other places along the Japan Sea coast.

The investigation in this area was carried out on June 4, 1966 in the intertidal and on July 27, 1966 in the subtidal zones. Additional observations were made several times during 1966 to 1969. The areas investigated were the outside (Station 1) and inside (Station 2) of Kabuto-iwa located at the entrance of the bay. Station 1, exposed place to wave action, consists of

a ledge facing west and subtidal steep slope which goes down to a depth of 9.6 m. Station 2 is a sheltered place, and consists of a shallow ledge and subtidal slope to a depth of 8 m.

The profile of the vertical distribution at Station 1 is shown in Fig. 12 and that of the vegetation at Station 2 in Fig. 13.

Station 1: The main belts in the intertidal zone were *Gloiopeltis furcata*, *Analipus japonicus* (basal portion only), *Corallina pilulifera*, and *Polysiphonia senticulosa*, and those in the subtidal zone were *Laminaria religiosa*, *Undaria pinnatifida*, *Costaria costata* and *Dictyopteris divaricata*. The supratidal zone was mostly bare. *Gloiopeltis furcata* occupied the upper intertidal zone but was not dense in the lower portion of *Gloiopeltis* belt. The vertical range of this plant was 25 to 35 cm wide at Station 1, however that of neighbouring sheltered places became narrower. The zone below the *Gloiopeltis* belt was a very narrow belt of *Analipus japonicus* bases. Only the bases remain because the plant usually passes summer season with the state of base. Below the *Analipus* belt, *Mytilus* sp. formed a dense population with a vertical width of about 18 cm. The vertical width of the *Corallina pilulifera* belt below the *Mytilus* belt was about 10 cm. This belt developed well on very gentle slopes and became vertically narrower on steep slopes. Associated with this species is a small amount of small thalli of *Ulva pertusa* which occurred in the lower portion of the belt. *Ulva pertusa* is not common on the outer shore but is abundant in the inner area of the bay. At the lowest level of the intertidal zone and the uppermost part of the subtidal zone *Polysiphonia senticulosa* formed a narrow belt. *Laminaria religiosa* sometimes occupied this zone.

In the subtidal zone the most distinct belt in the upper area is formed by *Laminaria religiosa* which occurred mainly between ELWS and a depth of 2.5 m. Associated with *L. religiosa*, *Undaria pinnatifida* f. *distans* and *Polysiphonia senticulosa* occurred between 1 and 2 m, however, in the upper part of the *Laminaria* belt there were no undergrowth plants, except for crustose coralline algae. Below the *Laminaria* belt, *Undaria* forms a narrow belt between a depth of 2.5 and 3.2 m mixed with *Desmarestia ligulata*, *Polysiphonia senticulosa*, *Symphyclocladia marchantioides* and a small amount of *Costaria costata*. *Mytilus edulis* dominated on vertical rock between 3.2 and 4 m below ELWS. On the surface of *Mytilus* shells several small red algae were found. They are *Antithamnion nipponicum*, *Pleonosporium pinnatum*, *Ptilota pectinata*, *Symphyclocladia marchantioides*, *S. latiuscula*, *Dasya sessilis*, *Gelidium vagum*, and *Rhodomenia pertusa*. Below a depth of 4 m *Costaria costata* formed an indistinct belt down to a depth

of about 4.8 m mixed with limited amounts of *Chrysymenia wrightii* and *Dasya sessilis*. Below the *Costaria* belt, *Dictyopteris divaricata* dominated between a depth of 4.8 and 9.6 m. Mixed with this species *Symphyocladia marchantioides*, *Rhodymenia intricata*, *Chrysymenia wrightii* and *Dasya sessilis* were occasionally observed. Small amounts of *Sorella repens* and *Phycodrys radicata* were found on rhizoidal filaments of *Dictyopteris* at about 6 m depth.

Station 2: The intertidal zone of this sheltered area has no distinct zonation except for the *Gloiopeltis* belt. However, in contrast to the vegetation on the exposed outer shore, the flora is comparatively rich. The highest belt was formed by *Gloiopeltis furcata* with a width of about 20 cm, approximately between the level of EHWS and MSL. Below the *Gloiopeltis* belt, in the offshore direction, *Dumontia simplex*, *Corallina pilulifera*, *Rhodomela latrix*, *Ulva pertusa*, *Scytosiphon lomentaria*, and *Sargassum thunbergii* occurred consecutively although sometimes they were mixed. Among them *Ulva pertusa* was most widely distributed. In the zone between MSL and ELWS *Cladophora opaca*, *Rhodoglossum japonicum*, *Chondrus pinnulatus*, *C. pinnulatus* f. *armatus*, *C. yendoi*, *Laurencia* sp. were found. On the uppermost slope of the subtidal zone, *Symphyocladia latiuscula* and a small amount of *Gracilaria textorii* occurred down to a depth of 40 cm and were followed by a *Gigartina tenera* belt which occupied the subtidal slope between 40 to 70 cm below ELWS. In the upper subtidal zone just mentioned, *Gelidium vagum*, *Lomentaria hakodatensis*, *Ceramium japonicum*, and *Colpomenia sinuosa* occurred sporadically. Below the *Gigartina* belt, *Ulva pertusa* dominated on the slope extending down to about a depth of 2 m below ELWS but gradually decreased in quantity. The deeper area was partly covered by crustose coralline algae. The bottom at 8 m depth is composed of pebbles and rocks on which no marine algae were found. In August, the ledge in the intertidal zone was mostly occupied by *Dictyota dichotoma*, and the subtidal zone of this inner area was occupied by *Ulva pertusa* on the upper slope to a depth of 4 to 5 m.

5. Yakishiri Island

Yakishiri Island (44°26'N., 141°26'E.) is located about 25 km off the western coast of Hokkaido. This island is mostly bordered by boulders and a gentle rocky slope. The investigation was carried out at two stations. Station 1 is a gently declining slope at Toyosaki on the north coast and Station 2 is a subtidal cliff of rock named Kamui-iwa about 800 m off the east coast. The investigation was carried out at Station 1 on August 5, 1964 and at Station 2 on August 1 and 2, 1965. An outline of this work

was previously reported (I. YAMADA, 1966).

The profile of the vegetation at Station 1 is shown in Fig. 14, and the vertical distribution at Station 2 is shown in Fig. 15.

Station 1: Plants occurring on a gentle slope between shoreline at high tide level (about 40 cm above ELWSI) and 50 m offshore were recorded along a line transect. The depth at 50 m offshore was 5.2 m.

The vegetation was very simple and typical of summer vegetation for shallow rocky slopes along the Japan Sea coast. In the area from the edge of the shore to 10 m offshore, where was 50 cm depth, the predominant plants were *Ulva pertusa*, *Rhodomela larix* and *Dictyota dichotoma*. *Corallina pilulifera* and *Grateloupia divaricata* also occurred in small amounts. *Gloiopeltis furcata* was not found in this area. The bottom between 10 and 30 m offshore consists of small boulders and sand. *Dictyota dichotoma* and *Chaetomorpha moniligera* appeared on boulders and *Phyllospadix iwataensis* grew on the sandy bottom. Small amounts of *Ceramium japonicum* and *Sargassum confusum* were also observed. In the area from 30 to 40 m offshore the bottom becomes somewhat rugged. The tops of rocks were

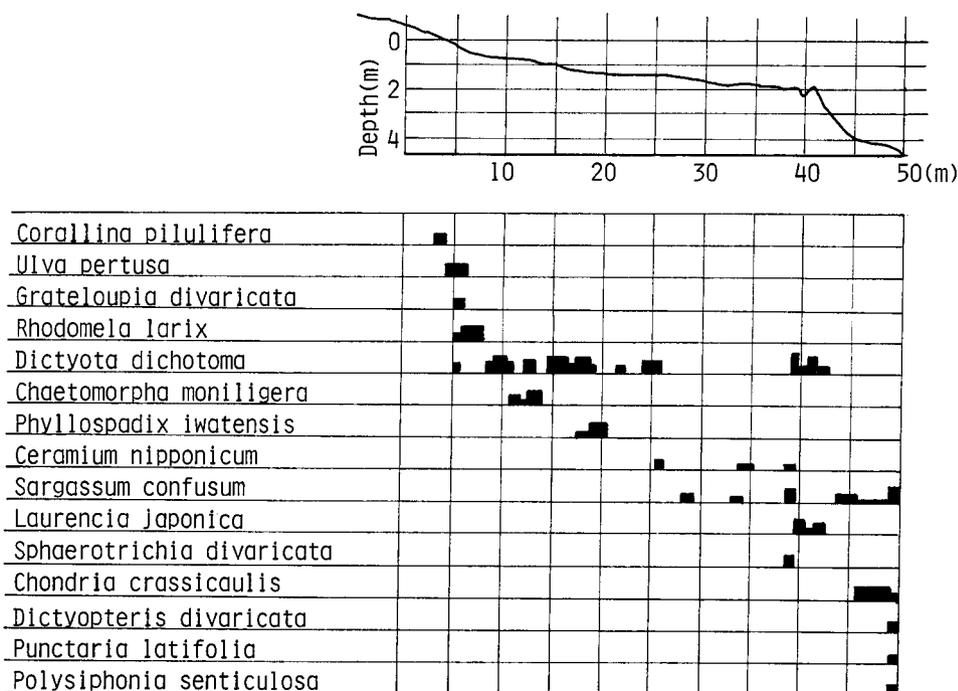


Fig. 14. Yakishiri Island (Loc. 5). Profile of the vegetation in the shallow subtidal zone at Toyosaki (August 5, 1964).

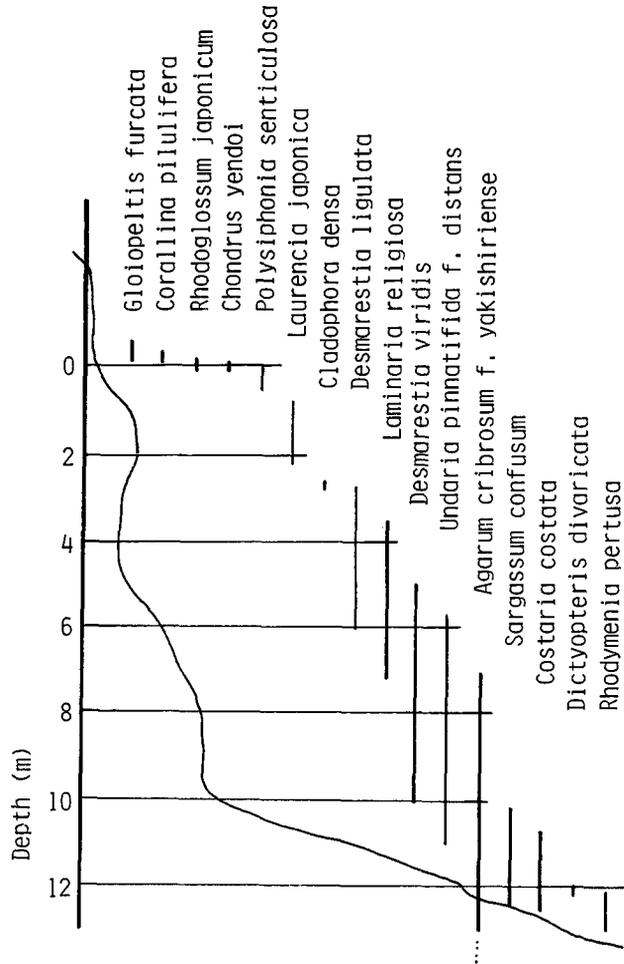


Fig. 15. Yakishiri Island (Loc. 5). Profile of the vertical distribution on the subtidal cliff at Kamui-iwa (August 1 & 2, 1965).

dominated by *Dictyota dichotoma*, and *Laurencia japonica* was scattered in other areas. In the area between 40 and 50 m offshore the bottom declined steeply down to 5.2 m. On the slope, *Sargassum confusum* and *Chondria crassicaulis* occurred relatively abundantly, and at the deepest part of the slopes investigated *Dictyopteris divaricata*, *Punctaria latifolia*, and *Polysiphonia senticulosa* appeared.

Station 2: Kamui-iwa is a rock protruding vertically several meters above the water surface. Thus, the area is regarded as an exposed place. The area investigated was the subtidal south-facing cliff extending down to 9.5 m and the successive rocky slope down to 13 m depth below ELWS.

This area was selected from knowledge obtained by the preliminary work in 1964 to elucidate the habitat of *Agarum cribrosum* f. *yakishiriense* (Syn. *A. yakishiriense*).

In the intertidal zone, *Gloiopeltis furcata* occurred sparsely on rocks or on barnacles between 80 and 40 cm above ELWS. This belt is indistinct compared to the usual belt on the Japan Sea coast, probably because these observations were made toward the end of the season. Near ELWS each of *Corallina pilulifera*, *Rhodoglossum japonicum* and *Chondrus yendoi* formed narrow belts from the top. In the subtidal zone, the uppermost part was occupied by *Polysiphonia senticulosa* and the successive zone, between 0.6 and 2.2 m below ELWS, was dominated by *Laurencia japonica*. In a shaded area below the overhang of a rock a small amount of *Cladophora densa* occurred at a depth of about 2.5 m. In the zone below about 3 m depth *Desmarestia ligulata* was scattered down to 6 m, and *Laminaria religiosa* formed a relatively dense community down to 7 m. *Dasya sessilis* occurred on the lower cliff between 5 and 9.5 m, where plants of *Laminaria* scarcely occurred. Below the *Laminaria* belt, both *Undaria pinnatifida* f. *distans* and *Agarum cribrosum* f. *yakishiriense* occurred relatively abundantly. The latter mostly dominated the bottom mainly from 9 m to 13 m. The main habitat of *Undaria* was found at about 8 m. Mixed with *Agarum*, *Sargassum confusum*, *Costaria costata*, *Dictyopteris divaricata* and *Rhodymenia pertusa* appeared on the slope below a depth of 10 m. *Agarum cribrosum* f. *yakishiriense* is a very interesting alga inhabiting the area restricted to only Yakishiri Island and neighbouring Teuri Island (I. YAMADA, 1974). The population density becomes greater below 10 m but the lower limit of the belt has not been elucidated (I. YAMADA, 1966).

The south coast of the island, called Shirahama, was also observed. On the shallow flat bottom at about 0.6 to 1 m near the intertidal zone, *Coccophora langsdorfi*, indigenous to the Japan Sea, occurred in patches. The community of *Sargassum sagamianum* var. *yezoense* developed densely on subtidal rock at a depth of 2 m. The vegetation at about 10 m in this area was generally very poor in summer: *Sargassum confusum*, *Dictyopteris divaricata* and *Dasya sessilis* were observed only in small amounts.

Rebun and Rishiri Islands

Rebun and Rishiri Islands are situated 18.5 to 55.5 km off the north-western coast of the Hokkaido mainland. The 20-meter depth contour line lies mostly within 1.85 km from shore except for the north coast of Rebun Island. The warm Tsushima Current flows toward the north-east in the

summer season, but the cold East Sakhalin Current and the Liman Current prevail in winter and sometimes floating ice comes near the island in winter. In the summer season the surface seawater temperature rises to about 20°C but falls to zero or -1°C in winter. However, detailed information on the coastal water conditions has not been reported.

6. Rebus Island

The investigation was carried out on the north-west shore of Todojima at the northernmost part of Rebus Island on August 12, 1969. The seawater temperature was 20°C. The station selected was an exposed rocky slope facing north. The bottom descends irregularly from the intertidal rock to a depth of 18 m. The point showing a depth of 18 m is about 200 m from the shore. Diving was done at depths of 4~5 m, 11 m, and 18 m.

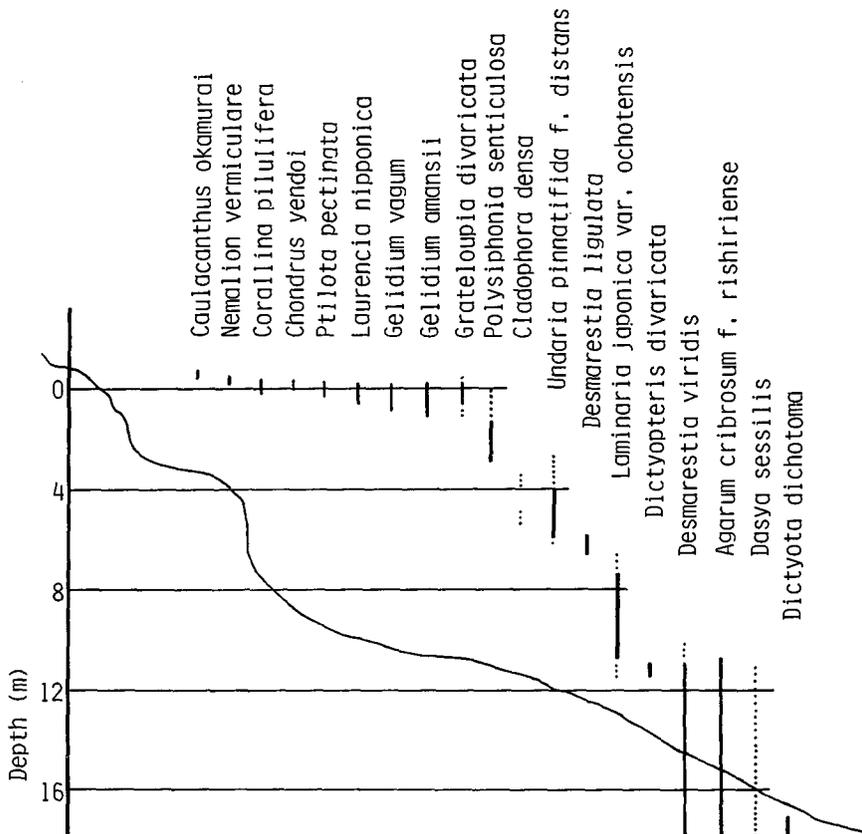


Fig. 16. Rebus Island (Loc. 6). Profile of the vertical distribution at Todojima (August 12, 1969).

The profile of the vertical distribution is shown in Fig. 16. In the intertidal zone, *Caulacanthus okamurai*, *Nemalion vermiculare*, *Chondrus yendoi*, *Ptilota pectinata*, *Gelidium amansii*, *G. vagum*, *Grateloupia divaricata* and *Corallina pilulifera* were found. *Chondrus yendoi* formed a distinct belt in the lower part, and *Nemalion vermiculare* was scattered on rocks or on shells of *Mytilus* sp. in the middle part, and *Caulacanthus okamurai* occupied the upper part. *Corallina pilulifera* formed mat-like aggregations in places from the upper to the lower part of the intertidal zone, but did not form a distinct belt. Small thalli of *Ptilota pectinata* occurred just below or within the *Chondrus yendoi* belt. *Grateloupia divaricata* occurred mixed with *Gelidium vagum* and *Gelidium amansii* in the area from the lower-intertidal zone down to a depth of 0.5 m or 1.0 m in the uppermost area of subtidal zone. Below the belt of *Grateloupia*, *Laurencia nipponica*, *Polysiphonia senticulosa*, and *Cladophora densa* occurred in the upper subtidal zone down to a depth of 3 m. Plants of *Laurencia* and *Polysiphonia* were tufted, but those of *Cladophora* formed small aggregations in relatively shaded places. In the zone between a depth of 4 and 6 m on a slope and in the upper part of a subtidal cliff *Undaria pinnatifida* f. *distans* formed a distinct belt. At this time *Undaria* was declining, and upper parts of thalli were mostly worn away. In the lower part of *Undaria* belt, a small amount of *Desmarestia ligulata* occurred. On the subtidal cliff between a depth of 6 and 8 m, no marine algae were found. At a depth of 8 m, *Laminaria japonica* var. *ochotensis* grew abundantly on rugged rocks or boulders. At a depth of 11 m, the bottom was dominated by *Laminaria japonica* var. *ochotensis* mixed with *Desmarestia viridis*, *Agarum cribrosum* f. *rishiriense*, *Distyopteris divaricata*, and small amounts of *Dictyota dichotoma* and *Dasya sessilis*. At a depth of 18 m, *Desmarestia viridis* dominated the large boulders and rocks mixed with *Agarum* and *Dasya*. *Agarum cribrosum* f. *rishiriense* is endemic on the coasts of Rebun and Rishiri Island. Thalli of this species at a depth of 18 m were relatively smaller in height and fewer in quantity than those at 11 m.

Algae were collected at several places on Rebun Island, namely at Kanedano-misaki, Nishiuedomari, Kabukai, Motoji, Shiretoko and Sashitoji.

In general, the vegetation in the intertidal zone was poor with the most species occurring in the lower part. At Kanedano-misaki, the north-east head of the island, *Chaetomorpha moniligera*, *Sphaerotrichia divaricata*, *Codium fragile*, *Lomentaria hakosatensis* and *Chrysymenia wrightii* were found in the intertidal zone. *Coccophora langsdorfii* dominated in the lower

intertidal as well as the uppermost part of the subtidal zone. This species occurred abundantly in somewhat shallow and flattened rocky bottom. At Nishiuedomari, on the north-west coast, the water transparency was very high but the vegetation was not rich. The dominating species in the subtidal zone were *Laminaria japonica* var. *ochotensis*, *Undaria pinnatifida* f. *distans*, *Desmarestia viridis* and *Polysiphonia senticulosa*. Other species such as *Dictyota dichotoma*, *Dictyopteris divaricata* and *Codium fragile* also occurred sparsely. The shore of Shiretoko, the southernmost area of the island, consists of shallow but broad rocky pools. From the intertidal zone of this shore, *Bonnemaisonia hamifera* epiphytic on *Sargassum confusum*, *Chondrus pinnulatus*, *Champia parvula*, *Palmaria palmata*, *Ptilota pectinata*, *P. pectinata* f. *litoralis*, *Acrosorium yendoi*, *Hypophyllum middendorffii*, *Chondria crassicaulis*, and *Odonthalia corymbifera* were collected. The southern limit of distribution in the Japan Sea of *Odonthalia corymbifera* was suspected to be on the coasts of Rebun and Rishiri Islands by FUKUHARA (1959 a). From the bottom at 7 m in the offshore area of Motoji, the southwest coast of the island, *Chorda filum* and *Dudresnaya minima* were collected.

7. Rishiri Island

Areas investigated were on the north coast of Rishiri Island. The intertidal and the successive upper subtidal zone down to a depth of 7 m was investigated on a rock of the exposed rocky shore of Beshi-misaki near Oshidomari Harbor (45°14'N., 141°14'E.), and deeper bottoms offshore of Oiso at depths of 7 m, 10 m and 21 m were investigated on August 17, 1969.

The profiles of the vertical distribution at Beshi-misaki and Oiso are shown in Fig. 17.

Beshi-misaki: The vegetation of this area was reported preliminarily in a paper on *Syringoderma australe*. This alga was collected for the first time in Japan during this diving work (MATSUNAGA and I. YAMADA, 1974). The area investigated consists of a short slope in the intertidal zone and a subtidal cliff down to 7 m. The area between 0.5 m and 1.0 m above ELWS was occupied only by barnacles and *Mytilus*. This upper area corresponds theoretically to the supratidal zone. However, it is frequently submerged by waves in rough weather. The upper intertidal zone about 50 cm above ELWS was also occupied by *Mytilus* on which *Goliopeltis furcata* and a small amount of *Nemalion vermiculare* were found. The area about 30 cm above ELWS was covered by small plants of *Laurencia* sp., *Chondrus yendoi* and *Chondria crassicaulis*. *Laurencia nipponica* formed a narrow

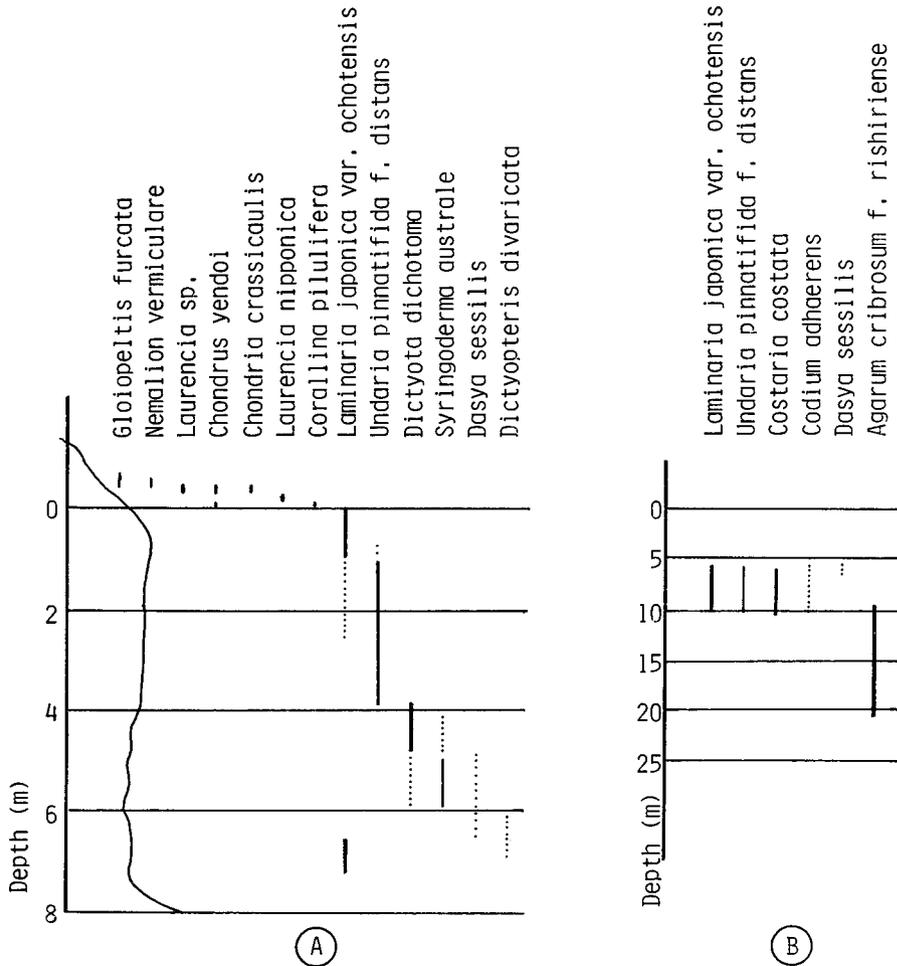


Fig. 17. Rishiri Island (Loc. 7). Profile of the vertical distribution at Beshi-misaki (A) and Ooiso (B) (August 17, 1969).

belt 20 cm above ELWS, and the area just below was dominated by *Chondrus yendoi* or *Corallina pilulifera*. The uppermost are of subtidal zone from ELWS down to about 1.0 m was completely dominated by young *Laminaria japonica var. ochotensis*. A suitable habitat for the young *Laminaria* plants was also found at 4 or 5 m depth near the area investigated. Below the belt of *Laminaria*, *Undaria pinnatifida f. distans* occurred in the area between a depth of 1.0 m (rarely 0.8 m) and 4 m. Below the *Undaria* belt the vegetation became very poor. On the subtidal cliff between 4 and 6 m depth *Dictyota dichotoma*, *Syringoderma australe* and *Dasya sessilis*

occurred sparsely, and at the bottom at 7 m *Dictyopteris divaricata* and adult plants of *Laminaria japonica* var. *ochotensis* formed aggregations on boulders. On September 26, 1974, diving work was carried out for collecting plants of *Syringoderma* in the area very near the previously investigated rock, and many *Syringoderma* plants were collected from the bottom at 11 m by Mr. T. KANEKO of Hokkaido Fisheries Experimental Station. During this work *Tokidaea corticata* (Syn. *Antithamnion corticatum*) and *Phycodrys radicata* were found relatively abundantly on the subtidal cliff from about 4 m down to about 10 m. *Agarum cribrosum* f. *rishiriense*, *Dictyopteris divaricata* and *Dasya sessilis* also occurred on this cliff.

Ooiso: The sea is shallow for some distance from the shore at Ooiso. The diving area for 21 m depth is about 2 km from the shore. The onshore vegetation was not observed. The rugged rocky bottom at a depth of 7 m was dominated by *Laminaria japonica* var. *ochotensis* mixed with *Undaria pinnatifida* f. *distans*, *Costaria costata*, *Codium adhaerens* and *Dasya sessilis*. On the relatively flat rocky bottom at 10 m *Costaria costata* dominated and was mixed with *Undaria*, *Laminaria*, *Codium* and *Agarum cribrosum* f. *rishiriense*. The very flat bottom at 21 m was mostly covered with *Agarum cribrosum* f. *rishiriense* as far as the eye could see. The *Agarum* community in this area was larger than any other place in these two islands and the thalli were large up to 60 cm in height. Thus, the subtidal vegetation at this area was characterized by the large communities of *Laminaria* and *Agarum*, and the occurrence of *Codium adhaerens*.

Okhotsk Sea Coast

8. Kitami-Esashi

Kitami-Esashi (44°56'N., 142°35'E.) is located on the northern part on the Okhotsk Sea coast. The shore line of this town consists of rocks, although the Okhotsk Sea coast consists mostly of sandy beach except for the west side of Shiretoko Peninsula. The coast at Kitami-Esashi is affected by a branch of the warm Tsushima Current, called the warm Sôya Current, in summer, but it is affected by the cold East Sakhalin Current in winter. Floating ice usually comes down from the north in January or February and the coast is closed by the ice until early April. It is said that plants growing in the intertidal or upper subtidal zones are scraped off by ice blocks during the winter season. As shown in Fig. 6 the seawater temperature in summer in the offshore area rises to 15°C in the surface layer but falls to 0°C at the 50 m layer which is in the cold water mass of the Okhotsk Sea. However, the temperature difference between the surface and 50 m-layers near the coast is less than that in the offshore area.

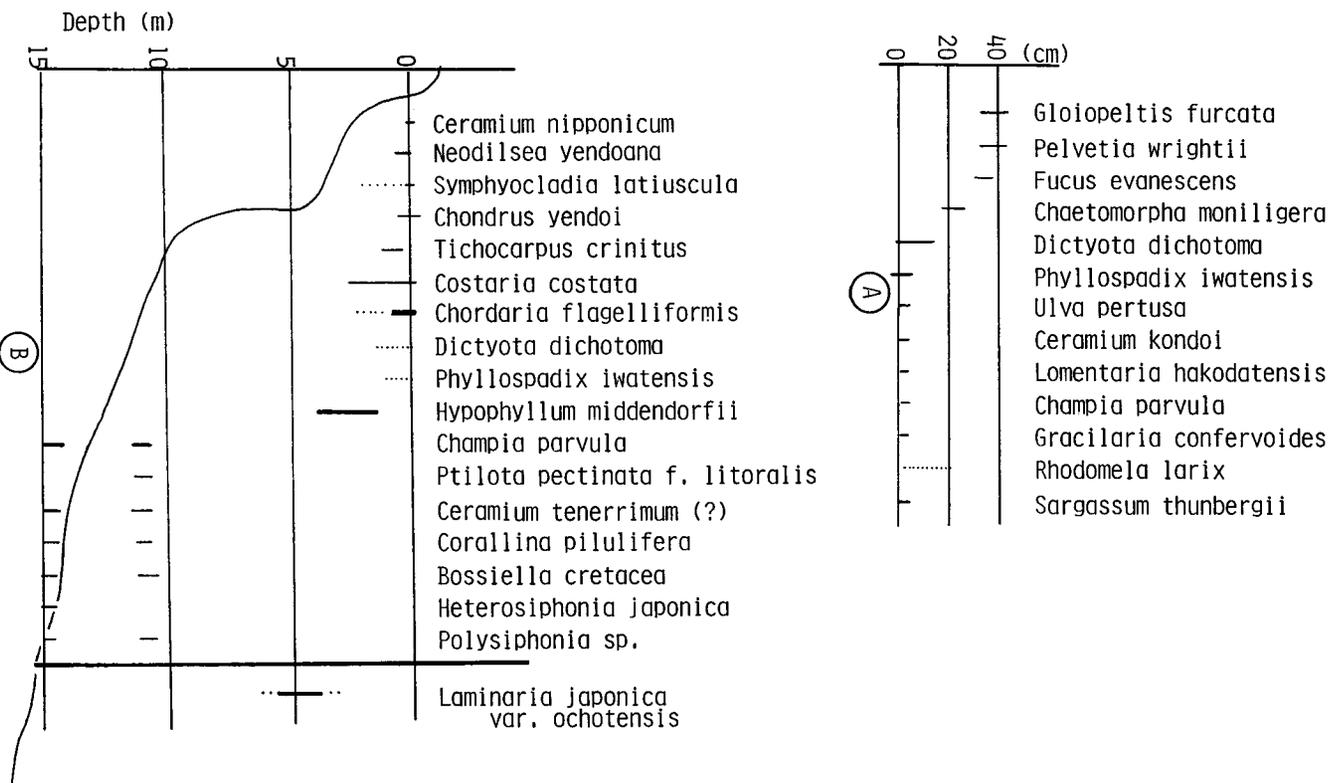


Fig. 18. Kitami-Esashi (Loc. 8). Profile of the vertical distribution in the intertidal (A) and subtidal zone (B) at Torinosaki (September 3 & 4, 1967).

This investigation was carried out at Toriinosaki, a small rocky headland near the town of Kitami-Esashi, on September 4, 1967. The intertidal investigation was carried out on a sheltered slope, and the subtidal was on an exposed area down to 15 m. The slope in the upper part of the subtidal zone descends gradually down to a depth of about 4 m, from where it descends steeply down to 8 m. Then, the bottom again descends gradually to a depth of 15 m, where is about 150 m from the shore. The bottom at 20 m consists of only sand. The diving work was carried out at depths of 0~8 m, 11 m, and 15 m.

The profile of the vertical distribution is shown in Fig. 18.

Exact levels of algal belts from ELWS were not recorded. On the upper intertidal zone, *Gloiopeltis furcata* formed a narrow belt and *Pelvetia wrightii* and *Fucus evanescens* occurred also in the upper intertidal zone, sometimes extending nearly as high on the shore as *Gloiopeltis*. *Fucus* is less abundant than *Pelvetia*. *Chaetomorpha moniligera* occurred below the *Fucus* belt. On the shallow and flat surfaces of the lower intertidal zone, *Dictyota dichotoma* and *Phyllospadix iwatensis* occurred abundantly mixed with *Ulva pertusa*, *Ceramium kondoi*, *Lomentaria hakodatensis*, *Champia parvula*, *Gracilaria verrucosa*, *Rhodomela larix* and *Sargassum thunbergii*.

In the subtidal zone, *Chordaria flagelliformis* formed a distinct belt from the lower intertidal zone down to a depth of 1.5 m although the lower limit of this species was about 2.5 m. *Symphyclocladia latiuscula*, *Neodilsea yendoana*, *Ceramium nipponicum*, *Dictyota dichotoma*, *Chondrus yendoi* and *Phyllospadix iwatensis* also occurred sparsely in this zone. Below the *Chordaria* belt a certain amount of *Dictyota dichotoma* occurred on somewhat flat rocks down to a depth of about 2 m. *Costaria costata* occurred relatively abundantly down to a depth of 3 m. One of the characteristic species occurring in the upper subtidal zone was *Hypophyllum middendorffii*, which occurred densely between depths of about 2 and 4.5 m. On the subtidal cliff just below the *Hypophyllum* belt, plants were scarce. At depths of 11 and 15 m, the bottom consists of relatively flat rock thinly covered with sandy mud. The plants occurring there were mostly small red algae. *Champia parvula* and *Ptilota pectinata* f. *litoralis* occurred abundantly, mixed with *Ceramium tenerrium?*, *Corallina pilulifera* and *Bossiella creta-cea*.

Except for *Costaria costata*, large plants were not found in the area investigated. *Laminaria japonica* var. *ochotensis* was found only on shallow rocky surfaces of about 4~5 m depth near the Harbor of Kitami-Esashi. Thus, the zonation in this area was characterized by a *Chordaria* flagel-

liformis belt, a *Hypophyllum middendorffii* belt and a *Champia parvula* belt. The *Laminaria japonica* var. *ochotensis* belt may also be added. The presence of the *Champia parvula* community in deep area, which has not been found along the other coasts of Hokkaido, is unique although it has not been determined that it is ubiquitous along the Okhotsk Sea coast. One of the interesting facts was that many female and male plants as well as tetrasporic plants of *Dictyota dichotoma* were collected from this area. Sexual plants of this species have not been reported from Hokkaido as far as I know. *Fucus evanescens* was also recorded. On the Okhotsk Sea coast, the western limit of this species may lie near Kitami-Esashi.

9. Utoro

Utoro is located near the base of the west coast of Shiretoko Peninsula. The coastline consists mostly of rocky shores. The coastal climate is similar to that of Abashiri. Observations were made on an exposed slope and in a sheltered area at Horobetsu on August 19, 1967, May 19 and July 18, 1968, and June, 13, 1969.

The shore at Horobetsu consists of a rocky terrace extending about 50 m offshore. Small channels enter the terrace to make pools in places. The exposed rocky slope of the outermost part of the terrace and the sheltered rock facing the channel were observed.

The profile of the zonation is shown in Fig. 19.

Exposed area: In May, 1968, on the 1.5 m high rocky slope four main belts were recognized. In the upper part, *Gloiopeltis furcata* formed a belt with a vertical range of about 30 cm. Below it was an *Analipus japonicus* belt of about 20 cm vertical range. Below the *Analipus* belt, young thalli of *Analipus* sp.* formed a conspicuous 80 cm-wide belt down to ELWS.

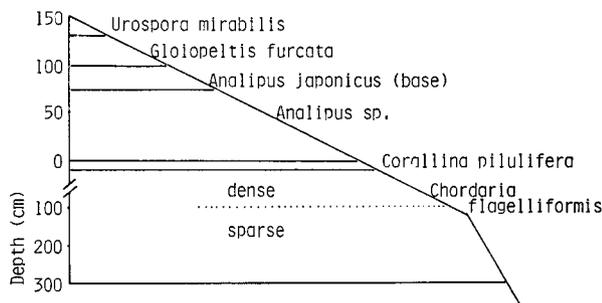


Fig. 19. Utoro (Loc. 9). Profile of the intertidal zonation on the open shore at Horobetsu (June 13, 1969).

* The taxonomic status of this plant is studied at present and it might be referred to *Analipus filiformis*.

Corallina pilulifera formed a narrow belt near ELWS. On June, 1969 the uppermost zone was occupied by *Urospora mirabilis*, and plants only the basal portions of *Analipus japonicus* were seen. *Analipus* sp. formed a remarkable belt during its luxuriant growth season. The area between the lowest part of the intertidal zone and the uppermost subtidal slope was dominated by *Chordaria flagelliformis*. The main habitat of this species was above 1 m depth, but the lower limit seemed to be about 3 m in this area. Thus, the zonation in this exposed area was characterized by *Gloiopeltis furcata*, *Analipus japonicus*, *Analipus* sp. and *Chordaria flagelliformis*.

Sheltered area: At the sheltered site the height of the rock terrace is only about 50~70 cm above ELWS; therefore, the intertidal zone is restricted to a narrow vertical range. In May, 1968, most of the slope situated at a edge of the terrace was densely covered with *Gloiopeltis furcata* mixed with small amounts of *Pelvetia wrightii* and *Fucus evanescens*. Just below the ELWS, *Sargassum thunbergii*, *S. confusum*, *Gigartina pacifica*, *Rhodomela larix*, *Corallina pilulifera* and *Monostroma angicava*, epiphytic on *Rhodomela larix*, occurred. In the tide pools near the shore *Grateloupia divaricata* and *Pterosiphonia bipinnata* were observed. In July, 1968, several additional plants appeared. They were *Blidingia minima* and *Chaetomorpha moniligera* in the lower intertidal zone, and *Polysiphonia senticulosa* and *Sargassum miyabei* in the uppermost part of the subtidal zone. In October, 1968, the upper intertidal zone was dominated by *Porphyra umbilicalis* and *P. pseudocrassa*. In June, 1969, the vegetation in the intertidal zone was strikingly similar to that found in May, 1968, but *Dumontia increassata* was found abundantly in the upper subtidal zone down to about 1 m depth. This plant was also abundant in tide pools. Another plant occurring abundantly was *Kornmannia zostericola* epiphytic on *Phyllospadix iwatensis*.

Nemuro Straits

East coast of Shiretoko Peninsula

Shiretoko Peninsula, which is about 65 km in length and 25 km in width, is located in the northeastern part of Hokkaido, protruding into the Okhotsk Sea. The west coast of the peninsula faces the Okhotsk Sea and the east coast faces Nemuro Straits and Kunashiri Island. In the northeastern coast, the shore is rimed with rugged rocky ledges, cliffs and gravel beaches while the southern coast consists mostly of boulders, gravel or sandy beaches. The depth of Nemuro Straits is about 2000 m at the north entrance, about 20 km from Shiretoko-misaki (cape). It becomes rapidly shallower southwards to about 200 m depth off Rausu. Further south, the bottom occurs at only

15~20 m at the south entrance between Notsuke Peninsula and the southern end of Kunashiri Island. Therefore, it is supposed that only a small quantity of water flows out to the Pacific from the Okhotsk Sea through Nemuro Straits.

The east coast of the peninsula is affected by the warm Sôya current, a branch of Thushima Current, from April to November and by the East Sakhalin Current and floating ice in winter.

The seawater temperature rises to 18°C in summer, but falls down to -1°C or less in winter.

Investigations were made at Shiretoko-misaki, Moireushi, Tokkarimui, Sashirui-misaki and Horomoi several times from August 1967 to March 1969. Diving was done at Shiretoko-misaki, Moireushi and Horomoi.

10. Shiretoko-misaki

The shore of Shiretoko-misaki is bordered by gravels and rocky terrace extending several hundred meters offshore. The outer area of the terrace descends steeply to 4~5 m below which the bottom becomes gradually deeper.

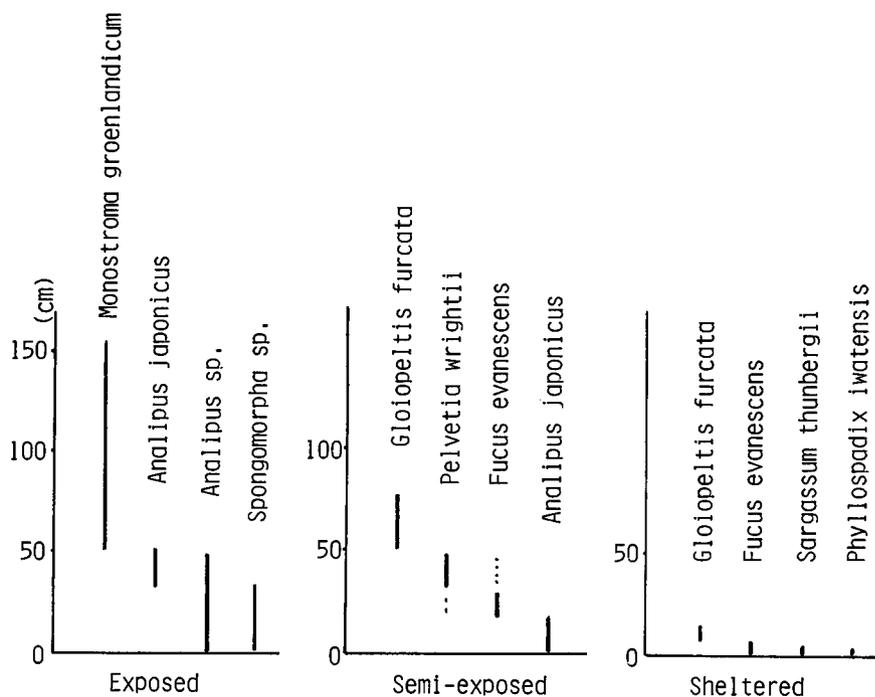


Fig. 20. Shiretoko-misaki (Loc. 10). Profile of the vertical distribution at exposed, semi-exposed, and sheltered places in the intertidal zone (May 17, 1968).

The rocky bottom reaches a depth of 20 m where is about 100 m from shore. Intertidal vegetation was investigated at sheltered, exposed, and semi-exposed places in May, 1968 and in June, 1969. The subtidal area extending to a depth of 24 m was observed in August, 1967 and in July, 1968.

Intertidal zone

The profile of the vertical distribution is shown in Fig. 20.

Exposed rocky slope: In May, 1968, the vegetation was characterized by three main belts. They were *Monostroma groenlandicum*, *Analipus japonicus* and *Analipus* sp. in descending order. *Spongomorpha* sp. was also found scattered in *Analipus* sp. belt. The thalli of *Analipus* sp. were young and only about 3 cm in height. In June, 1969, the lower intertidal zone was mostly covered with *Analipus* sp. which grew luxuriantly at this time. In the upper zone *Monostroma* was not found, but *Gloiopeltis furcata* occurred. Below the belt of *Analipus* sp., *Chondrus yendoi* and *Chordaria flagelliformis* occurred near ELWS, and *Alaria* sp. occurred from the ELWS down to 1 m or more. In the upper part of the subtidal zone, *Costaria costata* and young thalli of *Laminaria* were found.

Semi-exposed slope: The rocky slope observed lies halfway between a terrace head and the innermost part of a cove.

In May, *Gloiopeltis furcata*, *Pelvetia wrightii*, *Fucus evanescens* and *Analipus japonicus* formed intertidal belts from the top. *Pelvetia* and *Fucus* usually occurred together to make a *Pelvetia*—*Fucus* community. In the protected intertidal zone, however, *Pelvetia* occurred at a higher level than *Fucus*. On the semi-exposed rocky slope the typical *Pelvetia*—*Fucus* community was observed. Only the basal portion of *Analipus japonicus* remained in May. Below the *Analipus* belt, *Costaria costata* and *Phyllospadix iwataensis* occurred abundantly on the submerged flat substrate.

Sheltered shore: The sheltered area is found in the innermost part of a cove and consists of scattered relatively flat rocks and boulders. In May, *Gloiopeltis furcata* occurred on the upper rim of boulders, and *Fucus evanescens* grew abundantly on rocks below the *Gloiopeltis* belt. In this area there were many wide, shallow tide pools in which *Phyllospadix iwataensis*, *Ulva pertusa* and *Rhodomela larix* were found. *Sargassum confusum*, *S. thunbergii*, *Corallina pilulifera*, *Dumontia incrassata* and *Palmaria palmata* could be observed in deeper pools. *Eneliittosiphonia hakodatensis* was observed growing abundantly on *Rhodomela*. In June, 1969, *Blidingia minima* occurred conspicuously just below or within the *Gloiopeltis* belt. *Scytosiphon lomentaria* dominated in the lower intertidal zone.

Subtidal zone

The profile of the vertical distribution is shown in Fig. 21.

The subtidal investigation at Shiretoko-misaki was carried out on July 11, 1968. In the upper subtidal zone below the belt of *Analipus* sp., plants of *Chordaria flagelliformis*, *Odonthalia corymbifera*, *O. aleutica*, *Alaria* sp., *Cystoseira crassipes*, young thalli of *Laminaria* and *Phyllospadix iwatensis* occurred down to about 5 m. Among them *Alaria* sp. and *Phyllospadix iwatensis* were rather dominant. *Chordaria flagelliformis* occurred mainly down to 50 cm, but sometimes extends down to 2 m. *Saundersella simplex* was occasionally epiphytic on *Chordaria*. *Odonthalia corymbifera* grew

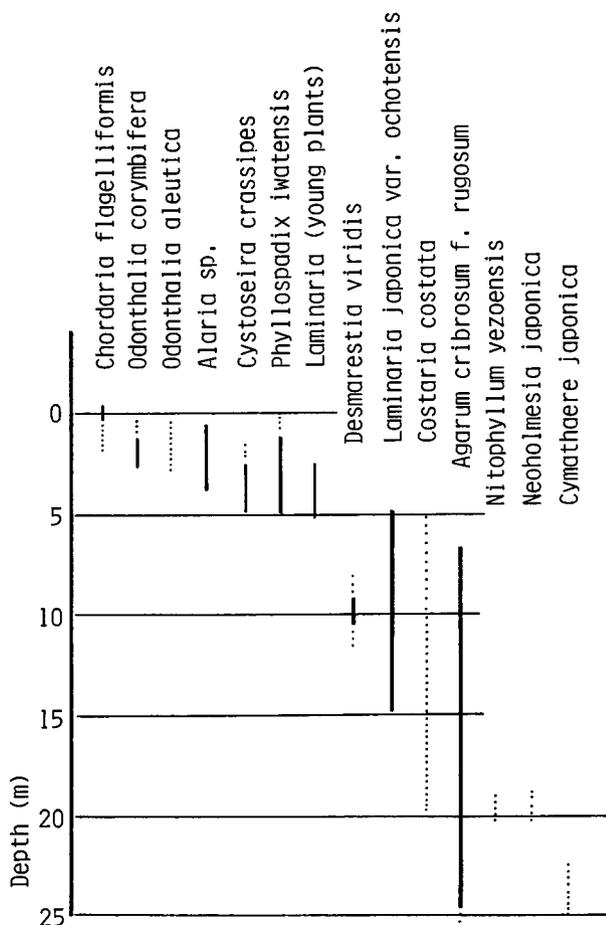


Fig. 21. Shiretoko-misaki (Loc. 10). Profile of the vertical distribution in the subtidal zone (July 11, 1968).

densely between depths of 1 and 3 m. At a depth of 5 m the bottom becomes somewhat flat making a subtidal ledge, on which *Cystoseira crassipes* and *Laminaria japonica* var. *ochotensis* occurred. Below this subtidal ledge, the bottom descends gradually, and several larger brown algae appeared abundantly. *L. japonica* var. *ochotensis* occurred between depths of 5 and 15 m, and *Agarum cribrosum* f. *rugosum* occurred abundantly below 7 m. *Desmarestia viridis* occurred mainly at 10 m. *Costaria costata* was scattered in the area from 5 m to 20 m, but did not form a distinct belt. At a depth of 20 m, small amounts of *Nitophyllum yezoense* and *Neoholmesia japonica* occurred on vertical rock faces where *Agarum cribrosum* f. *rugosum* was sparse. At a depth of 24 m, *Agarum cribrosum* f. *rugosum* and *Cymathaere japonica* occurred. Individuals of *Cymathaere japonica* were large, about 150 cm high and 30 cm wide, but they occurred sparsely in deeper waters in this area. This species is peculiar to the east coast of Shiretoko Peninsula. An interesting microscopic green alga, *Derbesia marina*, was collected from a depth of 20 m. Some individuals occurred on thalli of a sponge which attached firmly to the holdfasts of *Agarum*.

On August 13, 1967, diving was done at Akaiwa near Shiretoko-misaki. The vegetation observed at Akaiwa was similar to that of Shiretoko-misaki with *Agarum cribrosum* f. *rugosum* dominating the bottom below about 10 m, and *Laminaria japonica* var. *ochotensis* occurring down to 10 m but growing mainly on the bottom at 4 or 5 m.

11. Moireushi

Moireushi is about 15 km south of Shiretoko-misaki. There is a small cove protected by rugged rocky cliffs and ledges. The outer side of the cove is a very exposed place and the inner side is sheltered. Intertidal investigations were carried out in May, July and October of 1968 and June, 1969. Subtidal observations were made in July, 1968.

Intertidal zone

Exposed rocky slope : The profile of the vegetation is shown in Fig. 22.

The area investigated was a ledge facing east near the entrance to the cove. The ledge extends about 1.5 m vertically and about 7 m horizontally. From its edge, the substrate descends steeply. In May, 1968, the zonation from the top was as follows; Barnacle — *Gloiopelits furcata* — *Pelvetia wrightii* — *Fucus evanescens* — *Urospora mirabilis* — *Analipus japonicus* — *Analipus* sp. — *Halosaccion firmum* — *Chondrus yendoi* — *Chordaria flagelliformis*. Among them, the most distinct belt was *Analipus* sp., which densely covered the edge which was exposed to strong wave action. The *Pelvetia wrightii* belt was a distinct belt in which *Corallina pululifera* and

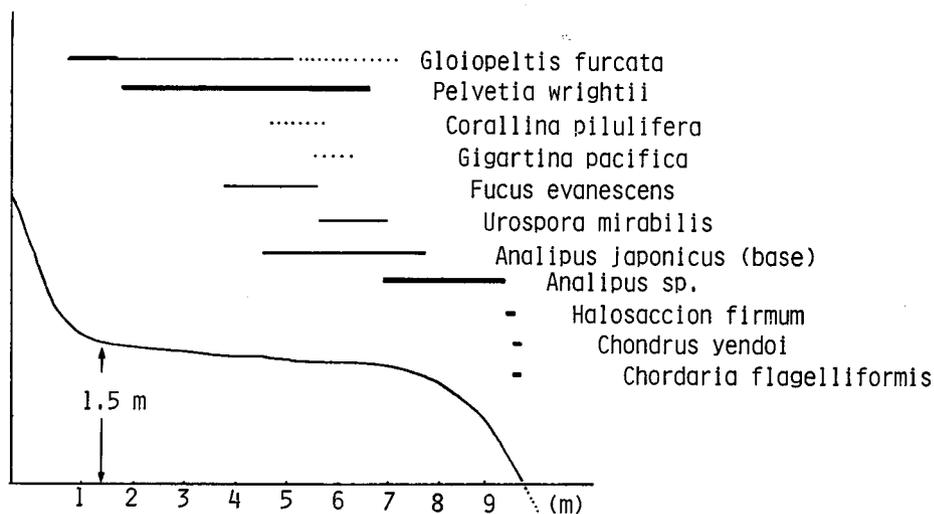


Fig. 22. Moireushi (Loc. 11). Profile of the vegetation in the exposed intertidal zone (May 16, 1968).

Gigartina pacifica were scattered. The *Urospora mirabilis* belt disappeared in July, and only the basal portion of *Analipus* sp. remained in October. *Gloiopeltis furcata* renewed itself in September.

Semi-exposed slope: The following vegetational pattern on a semi-exposed rocky slope facing a gully in outer area of the shore was observed; *Gloiopeltis furcata* — *Pelvetia wrightii*, *Fucus evanescens* — *Gigartina pacifica* — *Chondrus yendoi*. In this case, *Gigartina pacifica* characteristically covered the lower intertidal slope instead of *Analipus* sp., which occurred in more exposed places.

Sheltered place: The profile of the vegetation is shown in Fig. 23.

The vegetation appearing on a ledge in the cove was thought to be typical of sheltered areas at Moireushi. The flat ledge below the cliff extends about 10 m offshore. The vertical distance above the ELWS is only about 30 cm and the ledge is mostly submerged during high tides. From the cliff to the edge of the ledge, *Fucus evanescens* and *Halosaccion firmum* communities were remarkably lush. Within the *F. evanescens* community, *Pelvetia wrightii*, small amounts of *Analipus japonicus*, *Gigartina pacifica* and *Gloiopeltis furcata* were observed. Mixed with the *Halosaccion firmum* community, *Corallina pilulifera*, *Neodilsea yendoana*, *Rhodoglossum japonicum* and *Chondrus yendoi* were found. Below ELWS, *Chordaria flagelliformis*, *Costaria costata*, *Laminaria diabolica* and a small amount of *Alaria* sp. were observed. The *Halosaccion firmum* community at Moireushi is one of the most characteristic on the east coast of Shiretoko Peninsula.

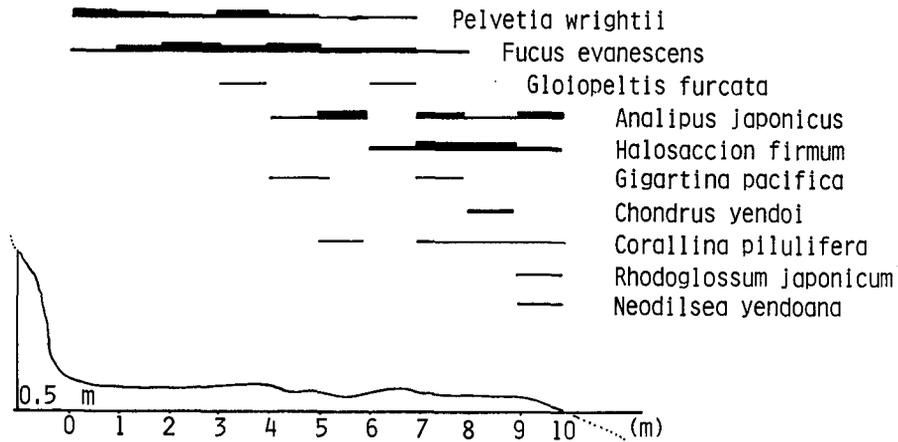


Fig. 23. Moireushi (Loc. 11). Profile of the vegetation in the sheltered intertidal zone (May 16, 1968).

Plants of this species were old in May, but they reestablished in July; therefore, this community can be seen throughout the year. A similar pattern of vegetation in sheltered places was found on a steeply declined rock between Moireushi and Pekinno-hana which is about 3 km north of the cove at Moireushi. The profile there was also composed of *Gloiopeltis furcata*, *Pelvetia wrightii*, *Fucus evanescens*, *Analipus japonicus* and *Halosaccion firmum* from the top. This place is protected by small offshore rocks and is not exposed directly to wave action. The vertical range of the *Halosaccion firmum* community in the lower intertidal zone was about 20 cm, which agreed well with that of the community found in the cove at Moireushi.

Subtidal zone

The profile of the zonation is shown in Fig. 24.

Subtidal vegetation was investigated at two sites outside the cove. One of the sites was a submerged cliff extending from an emerged rock down to more than 25 m, and the other was a gently sloping bottom extending down to about 7 m. Diving was done on July 13, 1968.

The investigation of the subtidal cliff was limited to the flora above 25 m in depth. On the emerged rock *Analipus* sp. *Chondrus yendoii* and *Chordaria flagelliformis* occurred. Below the *Chordaria* belt, *Odonthalia corymbifera* formed a belt on a gentle slope to a depth of about 1 m. The bottom below 1 m became quite steep. Below the *Odonthalia* belt, *Alaria* sp. mixed with *Ptilota pectinata* occurred down to 5.5 m, and *Laminaria diabolica* occurred between 4 and 10 m. On the bottom between 5.5 and 10 m *L. diabolica* was abundant and mixed with *Cymathaere japonica*,

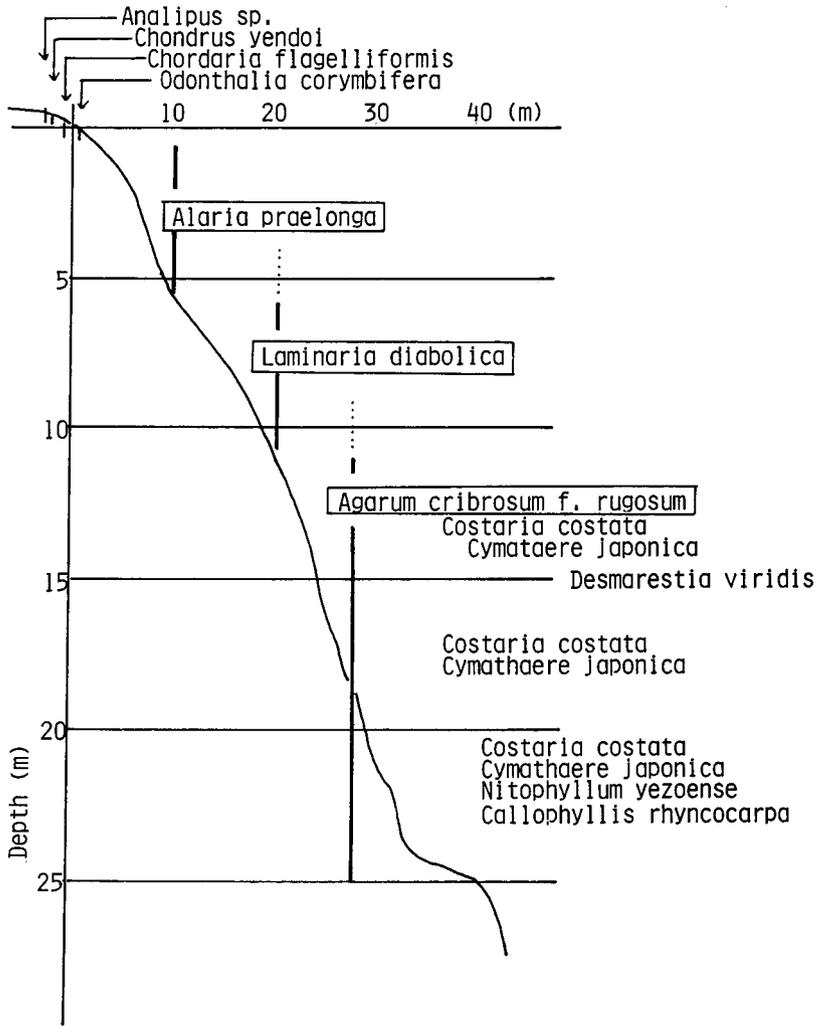


Fig. 24. Moireushi (Loc. 11). Profile of the subtidal zonation on the open shore (July 13, 1968).

Costaria costata and *Agarum cribrosum* f. *rugosum*. The bottom between 10 and 20 m was dominated by *A. cribrosum* f. *rugosum* mixed with *Costaria costata*, *Desmarestia viridis* and *Cymathære japonica*. The area below a depth of 20 m was mostly occupied by *A. cribrosum* f. *rugosum*, but *Nitophyllum yezoense*, *Neoholmesia japonica* and *Callophyllis rhyncocarpa* appeared on vertical faces and below ledges at a depth of 25 m. *A. cribrosum* f. *rugosum* apparently occurred below 25 m, but the lower limit

of its vertical distribution was not determined. *Derbesia marina* was also collected. The vegetation in this subtidal zone was very similar to that in Shiretoko-misaki.

The vegetation on the gently sloping bottom near shore was described together with the intertidal observations in the shallow waters of this shore. The shore consists of boulders and rocks. The shallow area above a depth of 1 m, *Phyllospadix iwatensis*, *Ulva pertusa*, *Rhodoglossum japonicum*, *Chondrus pinnulatus* and young thalli of *Laminaria diabolica* were found. A rare species, *Akkesiphycus rubricum*, occurred from 30 to 70 cm depth on this shore. On the bottom between 1 and 2 m, *Porphyra* sp. occurred densely. *Dictyopteris divaricata*, *Ulva pertusa*, *Cystoseira crassipes*, *Phyllospadix iwatensis* and *Tichocarpus crinitus* occurred on boulders or rocks scattered on the sandy bottom between depths of 3 and 4 m. Some *Monostroma angicava* was epiphytic on *Tichocarpus crinitus*. The irregular rocky bottom from 5 to 7 m was occupied by *Laminaria diabolica*, *L. saccharinensis*, *Costaria costata*, *Agarum cribrosum* f. *rugosum* and *Cystoseira crassipes*. *Coilodesme cystoseirae* was abundantly epiphytic on the erect thalli of *Cystoseira crassipes*.

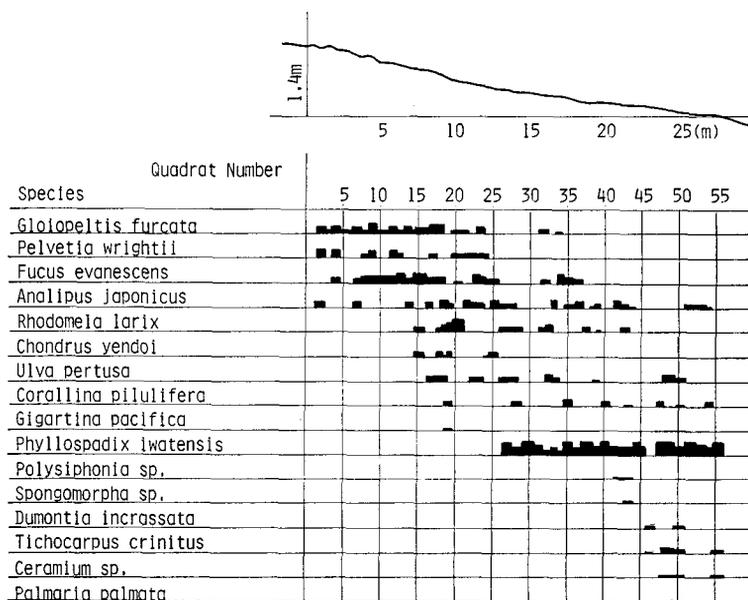


Fig. 25. Tokkarimui (Loc. 12). Profile of the intertidal vegetation on the gently declining rocky slope in May (May 13, 1968).

12. Tokkarimui

Tokkarimui is located about 10 km north of the town of Rausu. The shore consists of boulders, gravel and gentle rocky slopes. In this area the intertidal vegetation was investigated at two places. Station 1 was selected on a gentle rocky slope extending 26 m offshore. Coverage was recorded by using 50 cm × 50 cm quadrat frame. Station 2 was a rock, about 1.5 m above ELWS at the edge of the shore, from which the vegetation in various directions was examined. The investigation was carried out on May 13 and on July 10, 1968.

Station 1: The profiles of the vegetation in May and July are shown in Figs. 25 and 26, respectively.

The results obtained indicate that plants occurring abundantly in the intertidal zone in both spring and summer are *Gloiopeltis furcata*, *Fucus evanescens*, *Analipus japonicus*, *Rhodomela larix* and *Phyllospadix iwatensis*.

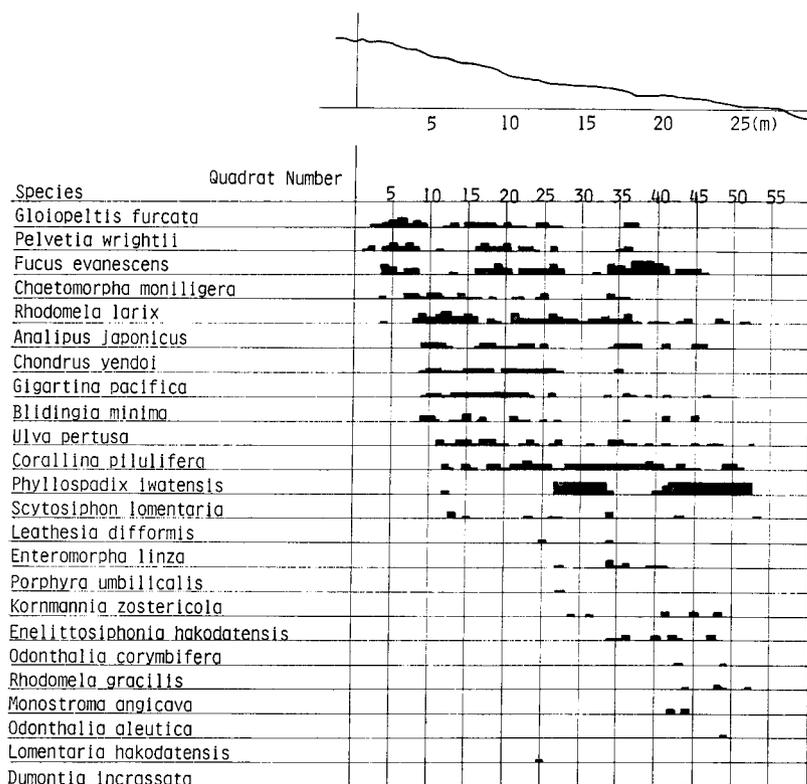


Fig. 26. Tokkarimui (Loc. 12). Profile of the vegetation in July at the same place in Fig. 25 (July 10, 1968).

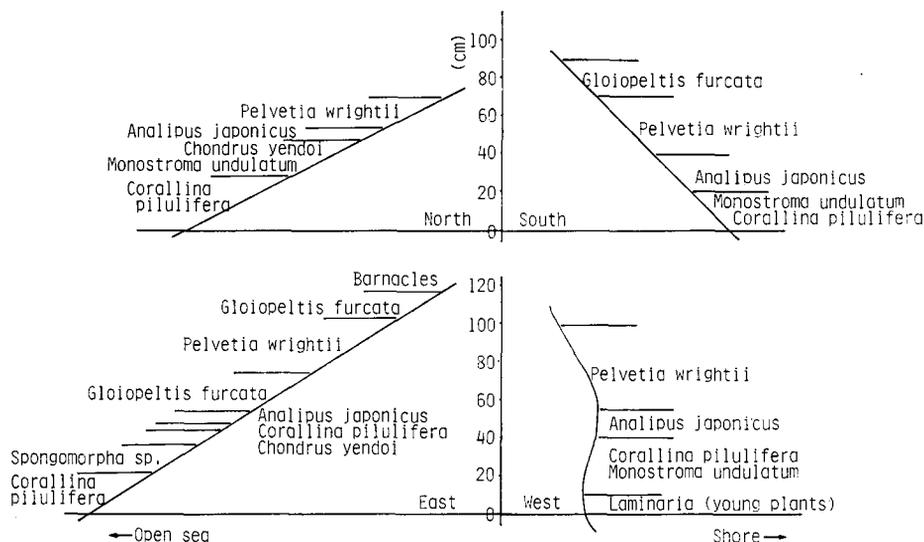


Fig. 27. Tokkarimui (Loc. 12). Profile of the zonation in four different directions on a rock near the shore (May 13, 1968).

In May, plants occurring relatively abundantly were mostly brown or red algae. *Ulva pertusa* was one exception (Fig. 25). In July, however, several other green algae such as *Chaetomorpha moniligera*, *Blidingia minima*, *Enteromorpha linza*, *Kornmannia zostericola* and *Monostroma angicava* appeared abundantly (Fig. 26). The lack of an *Analipus* sp. belt is notable. Judging from the composition of the vegetation, the vegetational pattern in this area is regarded as that of a sheltered area.

Station 2: The vegetation on slopes of the rock facing east, west, north and south were recorded (Fig. 27). The vegetation on the rock was essentially composed of *Gloiopeltis furcata*, *Pelvetia wrightii*, *Analipus japonicus* and *Corallina pilulifera*. The north and the west sides lacked the *Gloiopeltis* belt. The occurrence of *Chondrus yendoii* at a higher level on the north side, and east side facing the sea suggests that plants on both the sides are more strongly affected by wave action, because *Chondrus yendoii* occurs usually near MLWS. The seasonal difference in composition of species occurring on this rock is related to the temporal occurrences of several species in the *Corallina pilulifera* belt, such as *Monostroma*, *Spongomorpha* and *Ulva*.

13. Rausu

The vegetation of the intertidal zone at Rausu was investigated in two areas; Sashirui-misaki, a little north of the center of Rausu, and Chishô-

chô, a little south. Observations were made in May, July, and October, 1968, and in June, 1969.

Sashirui-misaki (44°04'N., 145°15' E.): The profile of the vertical distribution in May, 1968 is shown in Fig. 28.

The shore consists of large rocky terraces abundant in tide pools, gullies, channels, and boulders. The observations were made on the sloping plane of a rock in a semi-exposed place near a channel. The observed plane faces north and is 150 cm in height and slopes at an angle of 30°. Plants forming belts were *Gloiopeltis furcata*, *Pelvetia wrightii*, *Fucus evanescens*, *Ulva pertusa*, *Analipus japonicus* and *Chondrus yendoi*. The lower limit of the *Gloiopeltis* belt was a sharp line at 67 cm above ELWS. Both the lower limit of the *Gloiopeltis* belt and the upper limit of the *Pelvetia* belt corresponded to MSL, because the tidal range of this coast was similar to that of Abashiri (The Maritime Safety Agency, 1966; cf.

Fig. 4 in this paper). Similarly, the lower limit of the *Chondrus yendoi* belt corresponded to ELWS. *Pelvetia* and *Fucus* occurred mixed with each other, but the former occurred in an area a little higher than the latter. A small amount of *Analipus* sp. was observed at the edge of a rock facing the sea.

Chishô-chô: The profile of the vertical distribution in May, 1968 is shown in Fig. 29.

The shore consists of boulders, rocks and a small sandy beach. The observations were made on a rocky plane facing east in a tide pool opening to the sea. Plants forming belts were *Gloiopeltis furcata*, *Pelvetia wrightii*, *Fucus evanescens*, *Analipus japonicus*, *Corallina pilulifera* and *Chondrus yendoi*. In May, *Spongomorpha heteroclada* was abundantly epiphytic on *Phyllospadix iwatensis* occurring below ELWS. In July, *S. heteroclada*

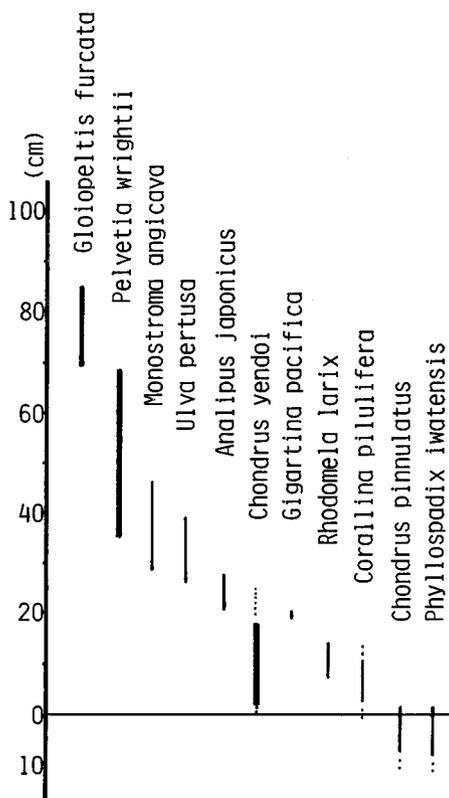


Fig. 28. Rausu (Loc. 13). Profile of the vertical distribution in the intertidal zone at Sashirui-misaki (May 18, 1968).

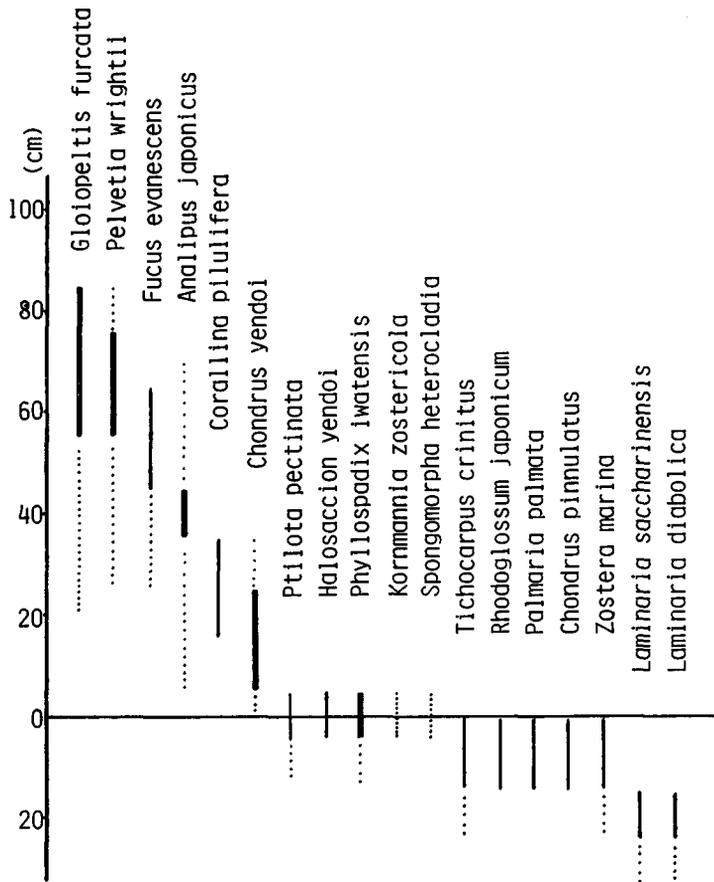


Fig. 29. Rausu (Loc. 13). Profile of the vertical distribution in the intertidal zone at Chishô-chô (May 15, 1968).

disappeared, and *Porphyra umbilicalis* newly appeared.

14. Horomoi

The shore of Horomoi is located about 15 km south of Rausu. The shore consists of sandy mud with small submerged rocks. The coastline is shallow for a long distance offshore. On August 15, 1967, diving was done at depths of 0~4 m, 6 m, 10 m and 16 m, the last point being about 2 km offshore.

Plants observed are shown in Table 3.

Zostera marina dominated on the sandy bottom near the shore. In this area small amounts of *Ulva pertusa*, *Chondrus yendoii*, *Neodilsea yendoana*, *Rhodoglossum japonicum*, *Chondrus pinnulatus* and *Odonthalia*

TABLE 3. Vegetational data from the subtidal zone at Horomoi on the east coast of Shiretoko Peninsula (Loc. 14) (August 15, 1967)

Distance	Depth (m)	Trans- parency (m)	Substrata	Dominant Species	Species
	0-2		Sandy mud and rock	<i>Zostera marina</i>	<i>Odonthalia corymbifera</i> <i>Chondrus pinnulatus</i> <i>C. yendoi</i> , <i>Neodilsea yendoana</i> <i>Rhodoglossum japonicum</i> , <i>Ulva pertusa</i>
	4		Sandy mud boulders	<i>Zostera marina</i>	<i>Laminaria diabolica</i> , <i>Bossiaella cretacea</i>
	6		"	"	"
ca. 1 km	10	4	Sand, rock	<i>Cymathaere japonica</i>	<i>Agarum cribrosum</i> f. <i>rugosum</i> <i>Cystoseira crassipes</i>
ca. 2 km	16	7	Rock boulders pebbles	<i>Agarum cribrosum</i> f. <i>rugosum</i>	<i>Desmarestia viridis</i> <i>Callophyllis rhyncocarpa</i> <i>Bossiaella cretacea</i>

corymbifera were also observed on rocks scattered. On the bottom at 4 m, *Zostera marina* still dominated. It was mixed with some *Laminaria diabolica* and *Bossiaella cretacea*. *Cymathaere japonica*, *Agarum cribrosum* f. *rugosum* and *Cystoseira crassipes* appeared on boulders at a depth of 10 m. At 16 m, *Agarum cribrosum* f. *rugosum* dominated over the rocky bottom mixed with *Desmarestia viridis* and *Callophyllis rhyncocarpa*.

North coast of Nemuro Peninsula

The north coast of Nemuro Peninsula is gravel shore, ledges, or cliffs in the eastern part, and sandy beach, boulders or small rocky shores in the western part. The coast is influenced by the terminal waters of the warm Sôya Current in summer but is closed by ice blocks from January to the end of March.

The investigation was carried out on June 3, July 16, and in September, 1970, near Nemuro Harbor (43°20'N., 145°35'E.) at large emerged rock named "Bara-jima" near Benten-jima, located a little offshore from Nemuro Harbor. The diving work was carried out at Bara-jima in July.

Another area used for intertidal observation was selected at Notsukamappu on the eastern part of the north coast of Nemuro Peninsula. The area observed was a gentle intertidal slope near the entrance to a small cove at Notsukamappu. This area was observed only on June 6, 1970.

15. Nemuro

Intertidal zone

The profile of the vertical distribution is shown in Fig. 30.

Bara-jima investigated is a reef-like rock emerging at ebb tides. In June, plants forming belts on the outermost rocky plane facing north were *Pelvetia wrightii*, *Fucus evanescens*, *Chondrus yendoi*, *Corallina pilulifera*, *Analipus* sp. and *Kjellmaniella gyrata* in order from highest. In other places, *Gloiopeltis furcata* and *Monostroma angicava* occurred just above or in the *Pelvetia* belt, and *Chordaria flagelliformis* occurred above the *Kjellmaniella* belt. Several species occurring abundantly in June at Bara-jima were *Bildingia minima* on a rocky slope of the inner part of Bara-jima, *Kornmannia zostericloa* epiphytic on *Phyllo-*

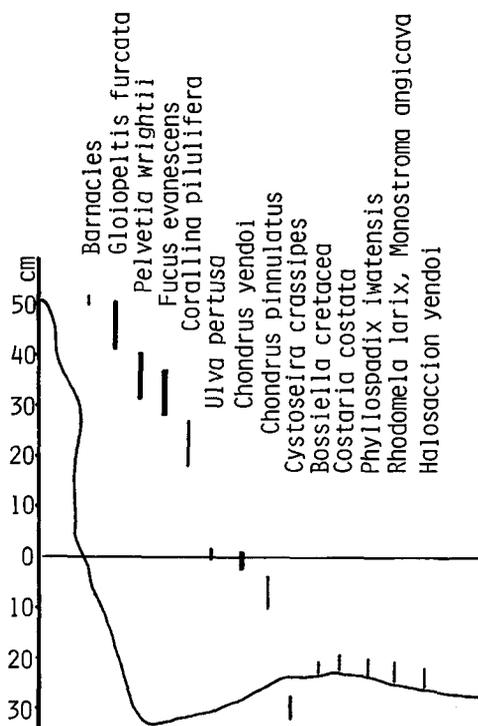


Fig. 30. Nemuro (Loc. 15). Profile of the vertical distribution in the intertidal zone at Bara-jima, near Nemuro Harbor (June 3, 1970).

spadix iwatensis in shallow pools, and *Pilayella littoralis* on the thalli of *Fucus evanescens*, which occurred in the lower intertidal zone near a small gully. *Halosaccion yendoi* was also observed in pools on the inner side of the reef. *Gigartina pacifica* occurred near ELWS in a small gully. *Sphaerotrichia divaricata* and *Rhodomela larix* were found in shallow pools. *Chondrus pinnulatus*, *Costaria costata* and *Cystoseira crassipes* were found below ELWS. In July, *Porphyra pseudocrassa* appeared abundantly on the rocky plane below the *Pelvetia* belt. *Analipus japonicus* occurred just above the *Analipus* sp. belt. *Dictyosiphon foeniculaceus* and *Saundersella simplex* were epiphytic on *Chordaria flagelliformis*. A lush growth of *Scytosiphon lomentaria* was also found in the shallow pools. In September, plants forming belts were *Gloiopeltis furcata*, *Pelvetia wrightii*, *Fucus evanescens*, *Porphyra pseudocrassa*, *Analipus japonicus* and *Kjellmaniella gyrata*. *Phyllospadix iwatensis* also occurred abundantly in the lower intertidal zone.

Subtidal zone

Diving work was done on the bottom extending from the outermost part of Bara-jima down to a depth of 15 m. The bottom declined gradually offshore. The diving at a depth of 15 m was about 400 m from Bara-jima. The observation was made at depths of 0~6.5 m and 14~15 m.

The profile of the vertical distribution is shown in Fig. 31.

In the intertidal zone, *Gloiopeltis furcata*, *Pelvetia wrightii*, *Porphyra pseudocrassa*, *Anelopus japonicus*, and *Chondrus yendoi* occurred. Below ELWS, *Chordaria flagelliformis* occurred abundantly to 1~1.5 m. *Saundersella simplex* and *Dictyosiphon foeniculaceus* were epiphytic on *Chordaria*. *Kjellmaniella gyrata* and *Costaria costata* also occurred below ELWS down to about 2 m, though less abundantly than those observed in the sheltered area near Bara-jima. On the bottom between 1 and 3.5 m, *Ptilota pectinata*, *Cystoseira crassipes*, *Tichocarpus crinitus*, *Ulva pertusa* and *Phyllospadix*

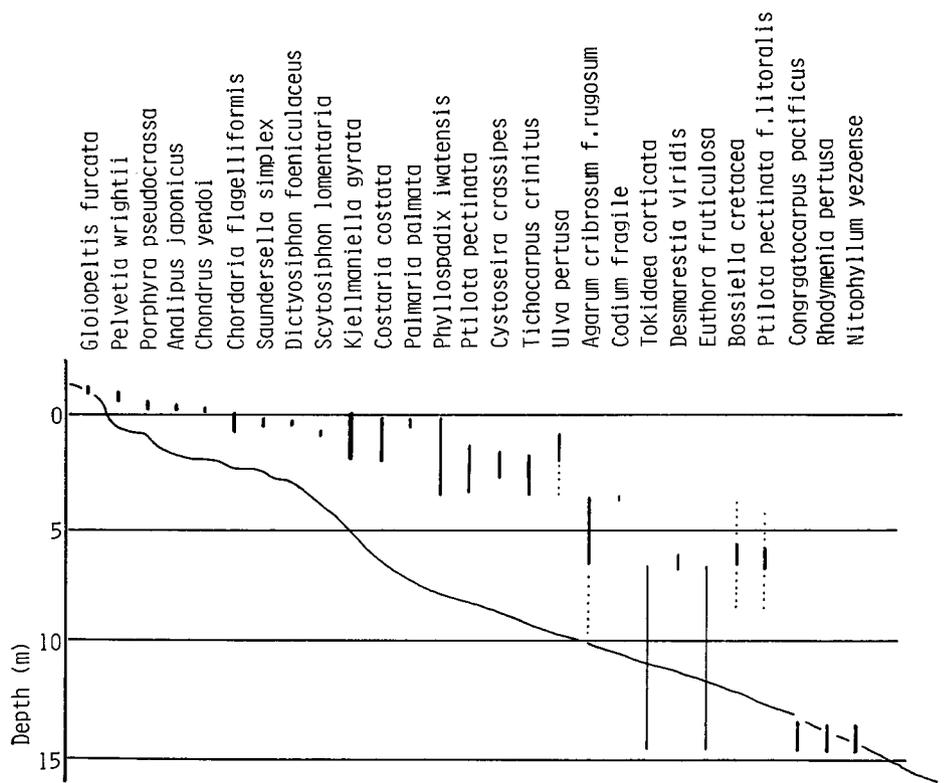


Fig. 31. Nemuro (Loc. 15). Profile of the vertical distribution in the subtidal zone offshore at Bara-jima, near Nemuro Harbor (July 16, 1970).

iwatensis occurred. Small thalli of *Ulvaria obsucula* var. *blyttii* occurred not abundantly on the bottom at about 4 m. *Agarum cribrosum* f. *rugosum* occurred comparatively abundantly between depths of 3.5 and 6 m though not so dense as in the deeper area in other places such as Shiretoko-misaki. This species occurred sparsely down to about 10 m. Mixed with the *Agarum* community, *Ptilota pectinata* f. *litoralis*, *Bossiella cretacea*, and *Desmarestia viridis* occurred in places. The area below the *Agarum* community was characterized by the occurrence of foliose and turf-forming species of red algae. Small red algae such as *Tokidaea corticata* and *Euthora fruticulosa* were common on small boulders and on empty shells. Four species of relatively large red algae, *Congregatocarpus pacificus*, *Rhodymenia pertusa*, *Nitophyllum yezoense* and *Pterosiphonia* sp., occurred relatively abundantly on boulders and rocks.

Thus, the vegetation in the subtidal zone of this area is characterized by the absence of *Alaria* and *Laminaria* belts as well as the occurrence of the red algae mentioned above.

16. Notsukamappu

The profile of the vertical distribution is shown in Fig. 32.

On June 6, 1970, the intertidal zone was occupied by *Gloiopeltis furcata*, *Corallina pilulifera*, *Rhodomela larix*, *Pelvetia wrightii*, *Fucus evanescens* and *Analipus japonicus*. Near EWLS *Dumontia incrassata*, *Rhodomela larix*, *Sargassum miyabei* and *Phyllospadix iwatensis* occurred on a gently sloping rocky bottom. In the uppermost part of the subtidal zone down to about 50 cm *Phyllospadix iwatensis*, *Cystoseira crassipes*, *Dumontia incrassata*, *Farlowia irregularis*, *Rhodomela larix*, and *Enelittosiphonia hakodatensis* epiphytic on *Rhodomela* occurred. The shore in this area was characterized by dense stands of *Dumontia*

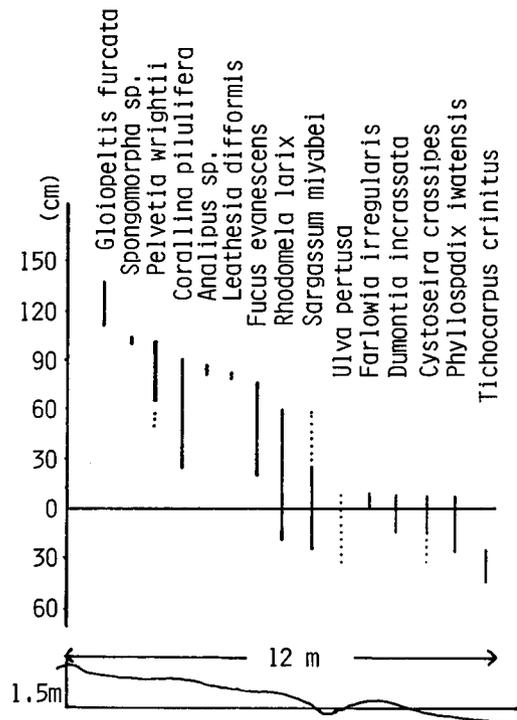


Fig. 32. Notsukamappu (Loc. 16). Profile of the vertical distribution on the semi-exposed intertidal zone (June 6, 1970).

incrassata in the uppermost part of the subtidal zone. *Dumontia incrassata* is regarded as a plant characteristic of sheltered areas. A small amount of *Analipus* sp. occurred in the zone usually occupied by *Pelvetia* or *Fucus*.

On the vertical slope of the gully, located about 1 km west of Notsukamappu cove, *Gloiopeltis furcata*, *Analipus japonicus*, *Fucus evanescens*, *Corallina pilulifera* and *Rhodomela larix* were observed above ELWS. *Tichocarpus crinitus*, *Chordaria flagelliformis*, *Ptilota pectinata*, *Agarum cribrosum* f. *rugosum* and *Cystoseira crassipes* were observed on a vertical slope between ELWS and 1.5 m depth. *Agarum* is sometimes found in such shallow waters in eastern Hokkaido but never on the western coast.

Thus, the vegetation of this area seems to be of a sheltered shore, although it faces the open sea. As in the case of Bara-jima, belts of *Alaria* and *Laminaria* were not observed there.

17. Nosappu-misaki

Nosappu-misaki is a cape located at the easternmost point of Hokkaido. The shore is lined with rugged rocks and small sandy beaches. The shore is affected by both the warm and cold currents. The terminal waters of the warm Sôya Current come down through Nemuro Straits and flow into the Pacific near Nosappu in summer season. In accordance with OKAMURA (1926), a demarcation line in the distribution of marine algae has been drawn at Nosappu-misaki since that time.

Intertidal observations were carried out at three stations on June 5 and July 20, 1970. Station 1 was a vertical rocky slope facing a somewhat

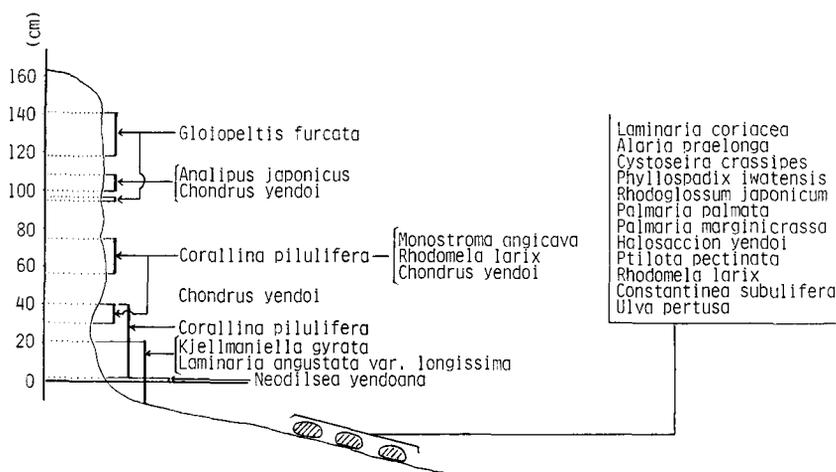


Fig. 33. Nosappu-misaki (Loc. 17). Profile of the zonation on the vertical rocky plane in a semi-exposed place (June 5, 1970).

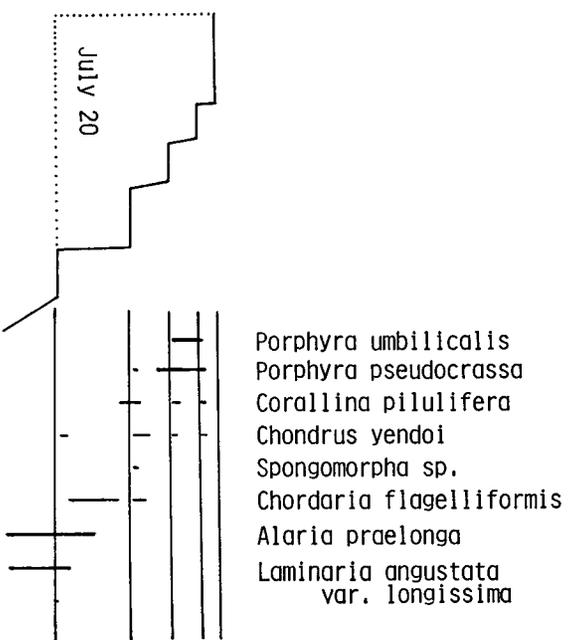
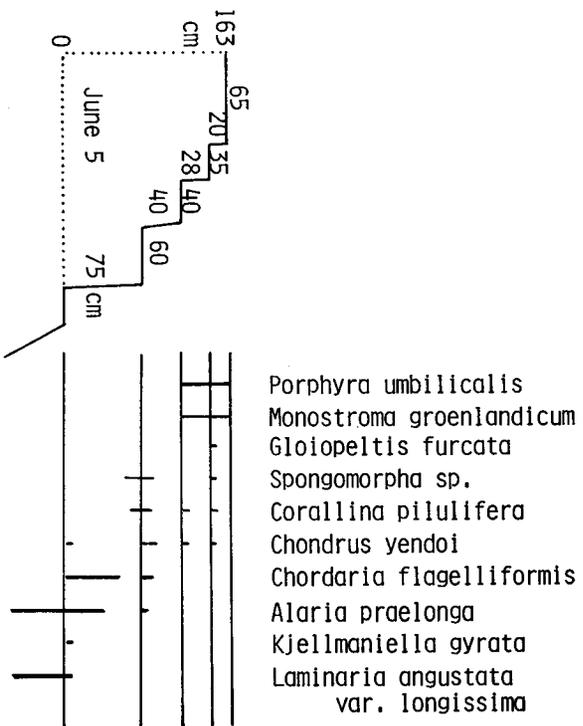


Fig. 34. Nosappu-misaki (Loc. 17). Profile of the vertical distribution at a stair like rock named Tobishima in June and July (June 5, July 20, 1970).

shoaling rocky beach on the northern side of the cape. Station 2 was a small stair-like rock near the cape head. Station 3 was the rocky shore just below the lighthouse of the cape. Subtidal observations were carried out on the bottom at depths of 2~2.5 m, 4.5 m, and 7.5 m in the offshore area of the cape on July 18, 1970.

Station 1: The profile of the zonation is shown in Fig. 33.

The vegetation at this site was observed only on June 5 just to see the vegetational pattern of a somewhat semi-exposed area, since the shore near Nosappu-misaki is mostly an exposed area. The main belts observed were *Gloiopeltis furcata*, *Analipus japonicus*, *Corallina pilulifera*, *Chondrus yendoi* and *Kjellmaniella gyrata* from the top. The shore is characterized by the *Kjellmaniella gyrata* belt found in the lower intertidal and uppermost part of the subtidal zone. The upper limit of this belt is about 20 cm above ELWS. The *Kjellmaniella* belt developed in sheltered areas more than in exposed areas. This belt was apparently replaced by an *Alaria* belt in highly exposed areas. The absence of *Porphyra* spp. and *Monostroma groenlandicum* common to exposed places near the cape was noticed. Below ELWS, *Laminaria angustata* var. *longissima*, *L. coriacea* and *Alaria praelonga* appeared relatively abundantly mixed with several species as listed in Fig. 33.

Station 2: The profile of the vegetation is shown in Figs. 34 and 35.

The vegetation was observed on both June 5 and July 20, 1970, on a rock, named "Tobishima", which is mostly submerged at high tide. The area observed faces the open sea and is stair-like in profile. On June 5, *Porphyra umbilicalis* and *Monostroma groenlandicum* occurred abundantly on the top of rocks. However, by July 20, *M. groenlandicum* had disappeared and been replaced by *Porphyra pseudocrassa*. *Chordaria flagelliformis*, *Alaria praelonga* and *Laminaria angustata* var. *longissima* occurred abundantly in the lower intertidal and upper subtidal zone; however, *Kjellmaniella gyrata* was not very abundant (Fig. 34). Each of the plants tended to occupy a definite area (Fig. 35). *Porphyra umbilicalis* was attached on both vertical and horizontal surfaces in the upper zone, but *Monostroma groenlandicum* occurred only on horizontal surfaces. This attachment preference may be related to the different abilities of the plants to endure desiccation. *Spongomorpha* sp., *Corallina pilulifera*, and *Chondrus yendoi* occurred higher in cracks and crevices, where moisture can be retained. At this station *Gloiopeltis furcata* and *Analipus japonicus* were scarce. This may be caused by the shape and height of the rock.

Station 3: Belt heights were not recorded at this station. On June

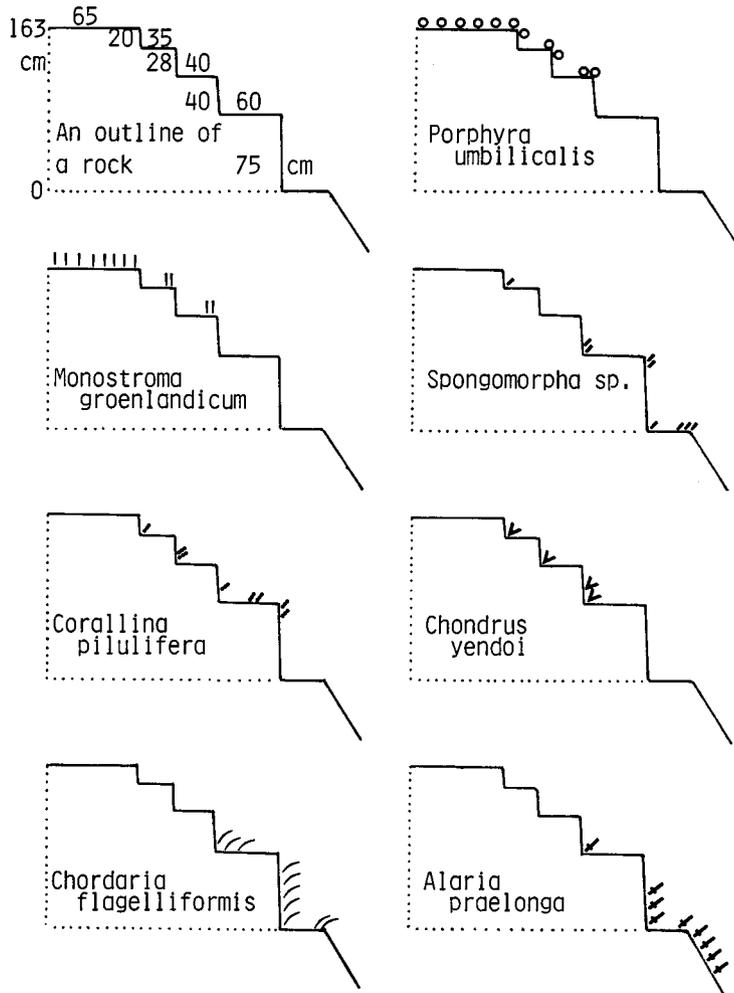


Fig. 35. Nosappu-misaki (Loc. 17). Profiles showing the positions occupied by several species at a stair like rock (June 5, 1970).

5, a rugged rocky plane in the upper and middle portion of the intertidal zone was mostly occupied by *Urospora mirabilis*, *Monostroma groenlandicum* and *Spongomorpha* sp. *Porphyra umbilicalis* and young plants of *P. pseudocrassa* were also observed. In the middle and lower zone, *Anatipus japonicus*, *Corallina pilulifera*, *Chondrus yendoii*, *Phyllospadix iwatensis*, *Chordaria flagelliformis*, young plants of *Laminaria*, *Kjellmaniella gyrata* and *Alaria praelonga* occurred. On July 20, the three species of green algae found in June had mostly disappeared in the upper zone; however,

Spongomorpha sp. still remained in the lower zone. In the upper zone *Porphyra pseudocrassa* predominated. The zonation observed from the top was as follows: Barnacles — *Gloiopeltis furcata* — *Porphyra pseudocrassa* — *Analipus japonicus* — *Corallina pilulifera* — *Chondrus yendoi* — *Spongomorpha* sp. — *Chordaria flagelliformis* — (*Kjellmaniella gyrata*) — *Alaria praelonga*.

Subtidal zone: The subtidal investigation was carried out in an offshore area a little to the north of the head of the cape. The strait between the cape and a reef named Kaigara-jima at the southern end of Kurile Islands is very shallow and the bottom from Nosappu-misaki declines very gently. The 7.5 m depth is about 1 km from the cape.

Species collected from three areas at depths of 2~2.5 m, 4.5 m and 7.5 m are listed below.

2~2.5 m

Ulvaria obsucula var. *blyttii*, *Ulva pertusa*, *Coilodesme cystoseirae*, *Cystoseira crassipes*, *Kjellmaniella gyrata*, *Alaria praelonga*, *Laminaria coriacea*, *L. diabolica*, *Porphyra* sp., *Neodilsea yendoana*, *Constantinea subulifera*, *Bossiella cretacea*, *Chondrus pinnulatus*, *Halosaccion yendoi*, *Ptilota pectinata*, *Odonthalia corymbifera*, *O. aleutica*.

4.5 m

Desmarestia ligulata, *Alaria praelonga*, *Agarum cribrosum* f. *rugosum*, *Laminaria angustata* var. *longissima*, *Callymenia ornata*, *Ptilota pectinata*, *Neoptilota asplenioides*.

7.5 m

Ulvaria obsucula var. *blyttii*, *Desmarestia viridis*, *Agarum cribrosum* f. *rugosum*, *Porphyra* sp., *Euthora fruticulosa*, *Turnerella mertensiana*, *Congregatocarpus pacificus*, *Pterosiphonia* sp.

Of these, some species such as *Laminaria angustata* var. *longissima* and *Constantinea subulifera*, are indigenous to the cold current area of the Pacific coast. However, *Arthrothamnus bifidus*, *Laminaria yezoensis*, *Agarum cribrosum* f. *cribrosum* and *Cirrulicarpus gmelini*, which are common to the Pacific side of Nemuro Peninsula, were not collected from the area investigated. These cold current species were collected at a small sandy beach near the cape as cast ashore plants in every season. Therefore, these species may occur in the subtidal zone near Nosappu-misaki.

Pacific Coast

18. Hanasaki

Hanasaki ($43^{\circ}17'N$, $145^{\circ}35'E$.) is located on the Pacific coast near the base of Nemuro Peninsula. The shore is washed by the cold Kurile Current throughout the year. The seawater temperature fluctuates between about $12^{\circ}C$ and $-1.5^{\circ}C$ during the year. Drift ice often comes in early February and goes away in the early March. The area where the intertidal vegetation was observed is an exposed rocky slope near the lighthouse of Hanasaki-bana. The subtidal zone here was also observed down to about 5 m. The bottom below 5 or 6 m in this area is mostly sand.

The profile of the vertical distribution of June is shown in Fig. 36 and that of September is shown in Fig. 37.

Observations in the intertidal zone were carried out on June 5, July 20, and September 27, 1970, and January 25, 1971. The description of the vegetation is based on the data from a rocky slope located on the south side of the headland just below the lighthouse. The slope is about 4 m in vertical height and about 8 m in length. The lower portion of the slope is irregular, but the upper portion is smooth. On June 5, on the highest

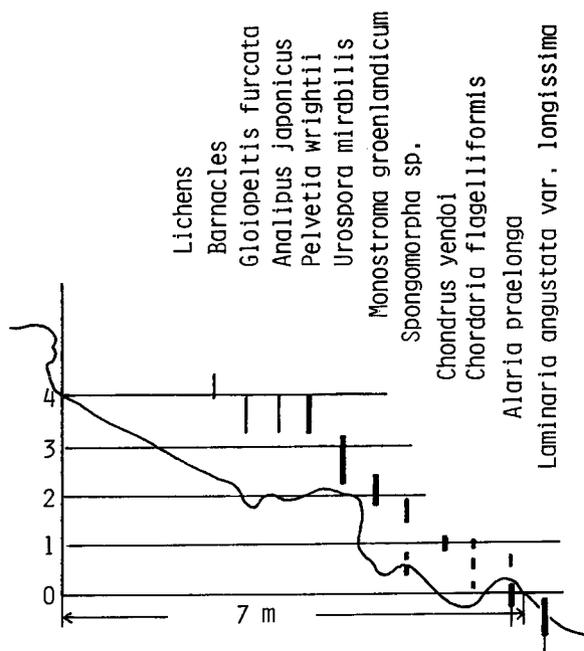


Fig. 36. Hanasaki (Loc. 18). Profile of the vertical distribution on the very exposed rocky intertidal zone in June (June 4, 1970).

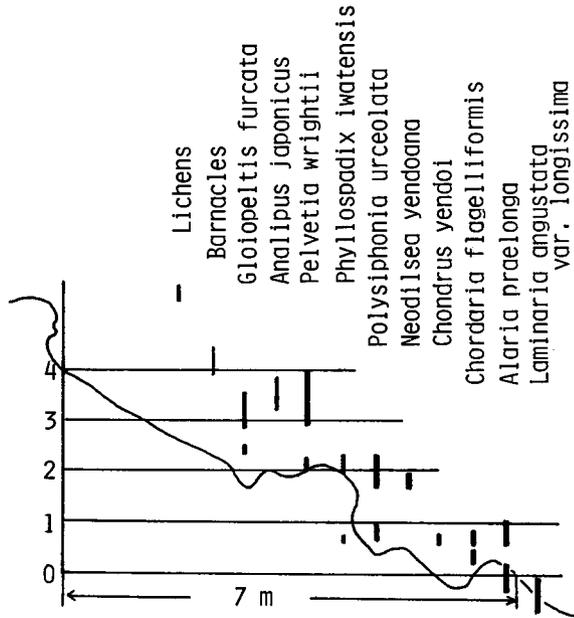


Fig. 37. Hanasaki (Loc. 18). Profile of the vertical distribution in September at the same place in Fig. 36 (September 27, 1970).

portion of the slope, barnacles, *Gloiopeltis furcata*, small thalli of *Pelvetia wrightii*, and *Analipus japonicus* occurred in small quantities. The next zone was occupied only by *Urospora mirabilis*. In a small pool in this *Urospora* belt, small thalli of *Alaria praelonga*, *Spongomorpha* sp., *Rhodomela larix* and *Corallina pilulifera* occurred in small amounts. A relatively flat rock below the *Urospora* belt was occupied by a mixed stand of *Urospora* and *Monostroma groenlandicum*. The successive vertical slope was covered by *M. groenlandicum* and *Spongomorpha* sp. in the upper portion, but was mostly occupied by *Chondrus yendoii* in the lower portion. The lower intertidal zone was mostly covered by *Chordaria flagelliformis* and *Alaria praelonga*, and *Spongomorpha* sp. occurred on a small protruding rock in this zone. In the zone below ELWS, *Alaria* and *Laminaria angustata* var. *longissima* occurred abundantly. In pools connected to the open sea near the investigated area, *Laminaria yezoensis* and *Cystoseira crassipes* were found. In July, *Urospora* disappeared, but a small amount of *Monostroma groenlandicum* occurring in the lower intertidal zone still remained. *Pterosiphonia bipinnata* occurred on larger barnacles in the mid intertidal zone. In September, *Pelvetia wrightii* on the upper portion of the slope had grown to 5~7 cm in height, and *Porphyra pseudocrassa* was found

below the *Pelvetia* belt. The rock face once occupied by *Urospora mirabilis*, and *Monostroma groenlandicum* in June was bare. *Polysiphonia urceolata* and *Neodilsea yendoana* were observed for the first time on rocks in the lower intertidal zone. In January, the vegetation in this area could not be observed because of stormy weather. On the higher slope near this area, a mixed stand of *Urospora mirabilis* and *Ulothrix flacca* occurred.

The subtidal investigation was carried out in the area in front of the rocky shore mentioned above on July 17, 1970. The surface seawater temperature was 12°C. The area observed was the shallow bottom between ELWS and about 2 m depth, and the rocky bottom at a depth of about 5 m. Plants observed abundantly in the former area were *Scytosiphon lomentaria*, *Chordaria flagelliformis*, *Punctaria latifolia*, *Porphyra* sp. *Odonthalia corymbifera*, *Tichocarpus crinitus*, *Cystoseira crassipes*, *Laminaria angustata* var. *longissima*, *Alaria praelonga* and *Phyllospadix iwatenensis*. *Pseudochorda nagaii* was found on this shallow bottom. On the bottom at 5 m *Laminaria angustata* var. *longissima* dominated and was mixed with *Alaria praelonga*, *Laminaria yezoensis*, *Porphyra* sp. *Neodilsea yendoana*, *Constantinea subulifera*, *Callymenia ornata*, *Rhodymenia pertusa*, *Congregatocarpus pacificus*, *Pseudophycodrys rainoskei*, *Odonthalia corymbifera* and *Neoptilota asplenioides*.

Thus, the subtidal area is characterized by the cold current species such as *Laminaria yezoensis* and *Constantinea subulifera*, but three typical cold current species, *Cirrulicarpus gmelini*, *Arthrothamnus bifidus* and *Agarum cribrosum* f. *cribrosum*, were not observed. These three species were found in relative abundance as cast ashore plants near the coast of Hanasaki. The failure to find these plants in situ might be the result of collecting no deeper than 5 meters.

19. Akkeshi, Daikoku-jima

Daikoku-jima Islet is located at the entrance to Akkeshi Bay. The outer shore of the islet consists of rugged rocks and is mostly exposed. The shore has a vegetation typical of areas affected by the cold Kurile Current. The surface seawater temperature rises to 13~16°C in the summer, although 18°C has been recorded in the innermost part of Akkeshi Bay. In winter seawater temperature falls to -1.3°C in January and February. Drift ice sometimes comes into Akkeshi Bay in February. The water transparency was only 4 m during diving work at midday in August. The subtidal investigation was done down to 13 m on the eastern side of the islet on August 26 and 27, 1966. A subtidal slope descends steeply from a ledge

to a depth of 8 m, and then the bottom declines irregularly down to 13 m. At a depth of 18 m it changes into a pebbly bottom.

The profile of the vertical distribution is shown in Fig. 38.

In this area, several species characteristic of the cold current region, *Arthrothamnus bifidus*, *Laminaria angustata* var. *longissima*, *L. coreacea*, *L. yezoensis*, *Cirrulicarpus gmelini* and *Constantinea subulifera* were found.

In the intertidal zone, *Porphyra pseudocrassa*, *Analipus japonicus*, a small amount of *Pelvetia wrightii*, *Corallina pilulifera*, *Chondrus yendoi* and *Chordaria flagelliformis* occurred in descending order. Of these, *Chondrus yendoi* dominated in the lower intertidal zone, and others were not abundant. In the subtidal zone four belts were recognized, namely the *Alaria*

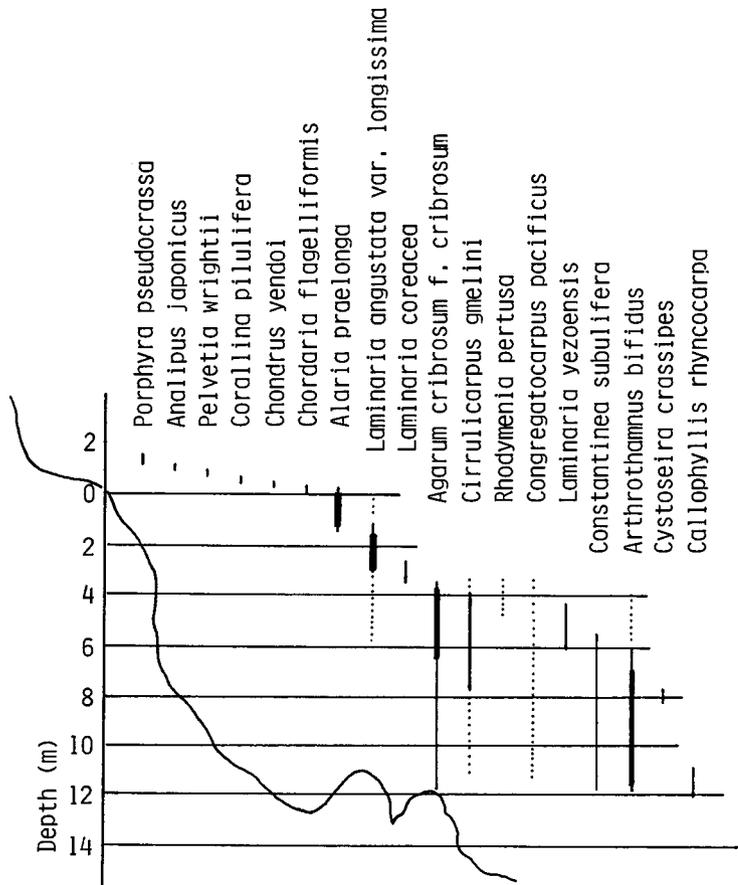


Fig. 38. Akkeshi (Loc. 19). Profile of the vertical distribution in the subtidal zone on the outer area of Daikoku-jima (August 26 & 27, 1966).

praelonga belt, the *Laminaria angustata* var. *longissima* belt, the *Agarum cribrosum* f. *cribrosum* belt and the *Arthrothamnus bifidus* belt. *Alaria praelonga* occupied the uppermost part of the subtidal zone down to 1.5 m mixed with *L. angustata* var. *longissima*, *Chordaria flagelliformis* and *Ptilota pectinata*. *Laminaria angustata* var. *longissima*, the most common and the largest brown algae in the eastern Pacific coast of Hokkaido, formed a distinct belt below the *Alaria* belt down to 3.2 m. This species, however, occurred from the lower intertidal zone down to 6 m deep. *Laminaria coriacea* occurred on the bottom at about 3 m. *Agarum cribrosum* f. *cribrosum* was found abundantly on the bottom between 3.5 and 6.5 m deep, but it was sometimes found in deeper waters at 10~12 m. In this zone *Cirrulicarpus gmelini*, *Rhodymenia pertusa*, *Congregatocarpus pacificus* and *Constantinea subulifera* occurred. *Laminaria yezoensis* occurred from depths of 4.2 to 6 m. In the zone below 7 m, *Arthrothamnus bifidus* was dominant down to 12 m mixed with *Constantinea subulifera*, *Cystoseira crassipes* and *Callophyllis rhyncocarpa*. Although *Arthrothamnus bifidus* could sometimes be observed in shallow gullies or pools on the shore, its main habitat was apparently in deeper waters. The southern limit of the distribution of this species appears to lie in the area between Akkeshi and Kushiro since it has not been recorded from Kushiro coast.

20. Kushiro

The subtidal vegetation was observed on the Okotsu coast about 4 km east of the center of Kushiro. The shore is a narrow sandy beach with a rocky terrace, which is submerged at high tide, extending about 70 m offshore. At the edge of the terrace the rock slopes relatively steeply to a depth of about 2 m and then descends more gradually. The subtidal vegetation was observed between the lower intertidal zone and a depth of 10 m. The investigation was carried out on August 27, 1965.

The profile of the vertical distribution is shown in Fig. 39.

The shallow bottom on the terrace is dominated by *Phyllospadix iwataensis* mixed with *Analipus japonicus*, *Chondrus yendoi*, *Rhodoglossum japonicum*, *Ulva pertusa*, *Rhodomela larix* and *Costaria costata*. Slightly deeper, near the edge of the terrace, *Alaria praelonga*, *Laminaria angustata* var. *longissima*, *Costaria costata* and *Tichocarpus crinitus* occurred. From the edge of the terrace to a depth of 2 m *Laminaria angustata* var. *longissima* dominated. In this belt, *Alaria praelonga* occurred from low tide level to 1 m, and both *Laminaria yezoensis* and *L. coriacea* occurred below about 1 m. The bottom below a depth of 2 m was somewhat flat and occupied by both *Laminaria coriacea* and *Phyllospadix iwataensis*. In this

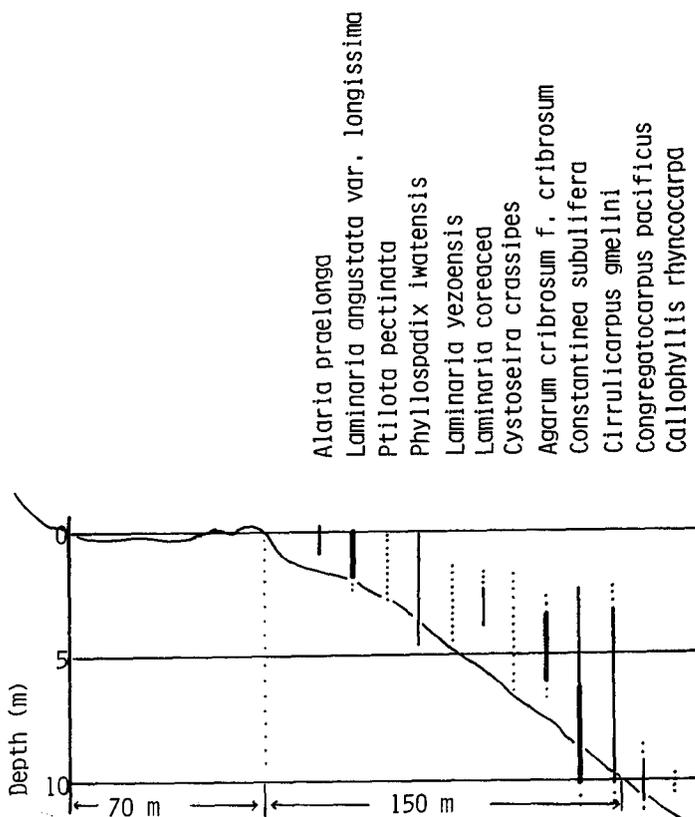


Fig. 39. Kushiro (Loc. 20). Profile of the vertical distribution in the subtidal zone at Okotsu coast (August 27, 1965).

belt, *Laminaria yezoensis*, *Constantinea subulifera*, *Cirrulicarpus gmelini*, *Ptilota pectinata*, *Agarum cribrosum* f. *cribrosum* and *Cystoseira crassipes* appeared. On the rocky bottom below about 4 or 5 m, *Constantinea subulifera* dominated down to a depth of 10 m mixed with *Cirrulicarpus gmelini*. *Agarum cribrosum* f. *cribrosum* could not be found below a depth of 6 m in this area. *Congregatocarpus pacificus* and *Callophyllis rhyncocarpa* were found at a depth of 10 m in the *Constantinea* belt.

21. Erimo-misaki

Erimo-misaki (41°55'N., 143°15'E.) is a cape protruding into the Pacific on the coast of the Hidaka district. The shore is influenced by the cold Kurile Current throughout the year; however, in summer a part of the warm Tsugaru Current flows eastward along offshore of Hidaka from Tsugaru Straits and turns south near Erimo-misaki. Therefore, the coastal waters

of Hidaka take on the character of a somewhat warm current region compared with Kushiro or Akkeshi (CHIHARA, 1972). The shore of Erimo-misaki is lined with rocky cliffs, rugged rocks, and reefs extending in a southeasterly direction. Intertidal observations were made on a rock located on the east side of the cape on August 30, September 29, and November 14, 1966, and March 30, 1967. No subtidal observations were made.

The profile of the vegetation is shown in Figs. 40 and 41.

In this area the shore is mostly exposed to wave action. An exposed vertical cliff and a rocky slope of a semi-exposed area were selected for investigation. At the exposed site the main belts were formed by *Gloiopeltis*

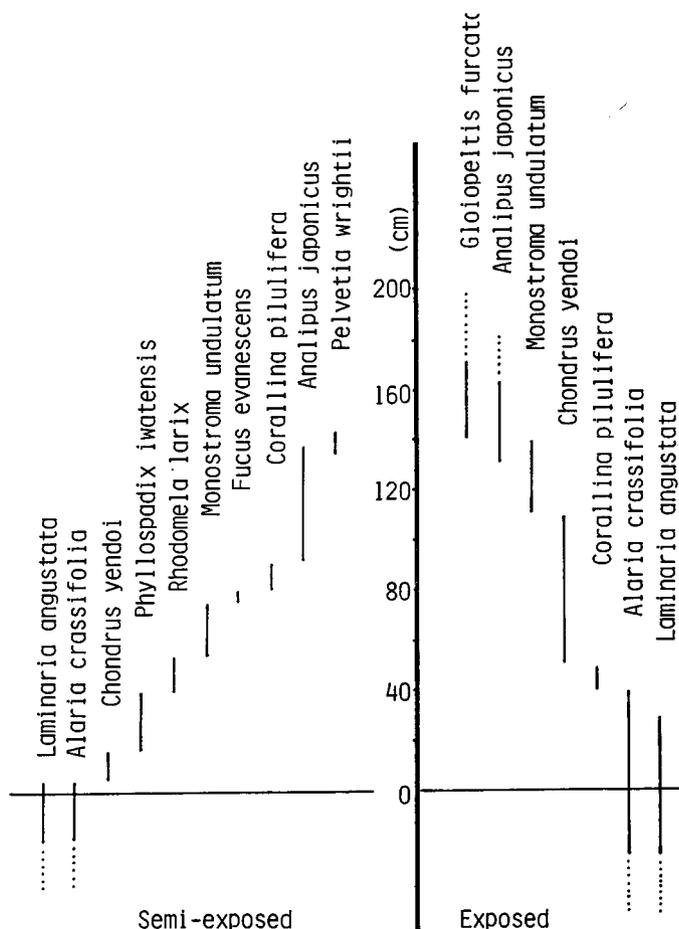


Fig. 40. Erimo-misaki (Loc. 27). Profile of the vertical distribution at exposed and semi-exposed rocky slope (March 30, 1967).

furcata, *Analipus japonicus*, *Chondrus yendoi*, *Corallina pilulifera*, *Alaria crassifolia* and *Laminaria angustata* from the top. On the other hand, *Pelvetia wrightii*, *Fucus evanescens*, *Rhodomela larix* and *Rhyllospadix iwatensis* formed belts from the top down on the semi-exposed rocky slope (Fig. 40). According to season, several temporal species such as *Porphyra*, *Monostroma*, *Ulva*, *Lomentaria*, or *Polysiphonia* were observed as epiphyte on *Corallina*, *Analipus*, or on other algae. The semi-exposed slope was observed in August, September, November and the following March, at which time the main belts were formed by *Pelvetia*, *Analipus*, *Corallina*, *Rhodomela* and *Chondrus* (Fig. 41). On the shore near Erimo-misaki, *Halosaccion firmum* sometimes formed a dense community at a level just above the *Chondrus* belt. This distinct *Halosaccion firmum* belt was very similar to that found at Moireushi on the east coast of the Shiretoko Peninsula. Subtidal observations were not carried out; however, plants washed ashore near Erimo-misaki were very similar to those from Kushiro, Akkeshi, or Hanasaki, namely *Constantinea subulifera*, *Cirrularcarpus gmelini* and *Agarum cribrosum* f. *cribrosum*.

22. Muroran

Muroran is located at the entrance of Uchiura Bay on the Pacific coast of southern Hokkaido. The coastal waters are influenced by both the warm Tsugaru Current and the cold Kurile Current. The warm current prevails in summer and the cold current in winter. The tidal range is large and was 208 cm between EHWS and ELWS in 1967. The surface seawater temperature rises to about 20°C in summer and falls to 2°C in winter.

Intertidal observations were made at Charatsunai in front of the Institute

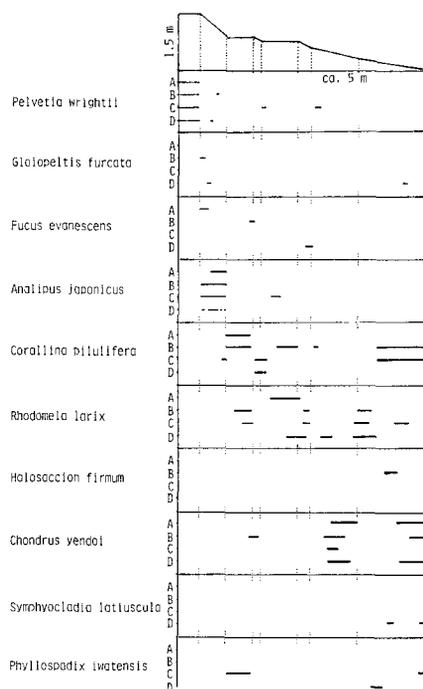


Fig. 41. Erimo-misaki (Loc. 21). The occurrence of several marine plants in August (A), September (B), November (C), and the following March (D) on the same rocky slope (August 30, September 29, November 14, 1966 and March 30, 1967).

of Algological Research of Hokkaido University on April 25, 1966. The shore of Charatsunai consists of rugged rocky terraces, cliffs, and a small pebble beach. A rock near a gully was observed as an example of exposed intertidal vegetation. Subtidal observations were made on a subtidal slope between the lower intertidal zone and a depth of 10 m on September 19, 1968 at Charatsunai.

Intertidal zone: On the exposed rock in the intertidal zone, the main belts observed were, from the top, *Gloiopeltis furcata*, *Analipus japonicus*, *Sargassum thunbergii*, *Chondrus yendoi* and *Alaria crassifolia*. In the *Gloiopeltis* belt, *Porphyra yezoensis*, small thalli of *Ulva pertusa* and *Analipus japonicus* occurred not abundantly. In the *Analipus* belt, *Ulva pertusa*, *Monostroma angicava* and *Corallina pilulifera* occurred in places. *Sargassum thunbergii* occurred relatively abundantly of the *Chondrus yendoi* belt corresponded approximately to ELWS. In the lower portion of the *Chondrus yendoi* belt, *Rhodoglossum japonicum* sometimes formed aggregations. *Alaria crassifolia* occurred densely below the *Chondrus* belt into a deeper area where it was mixed with *Polysiphonia senticulosa*, *Rhodomela gracilis* and *Ptilota pectinata* in the upper portion of the belt and with

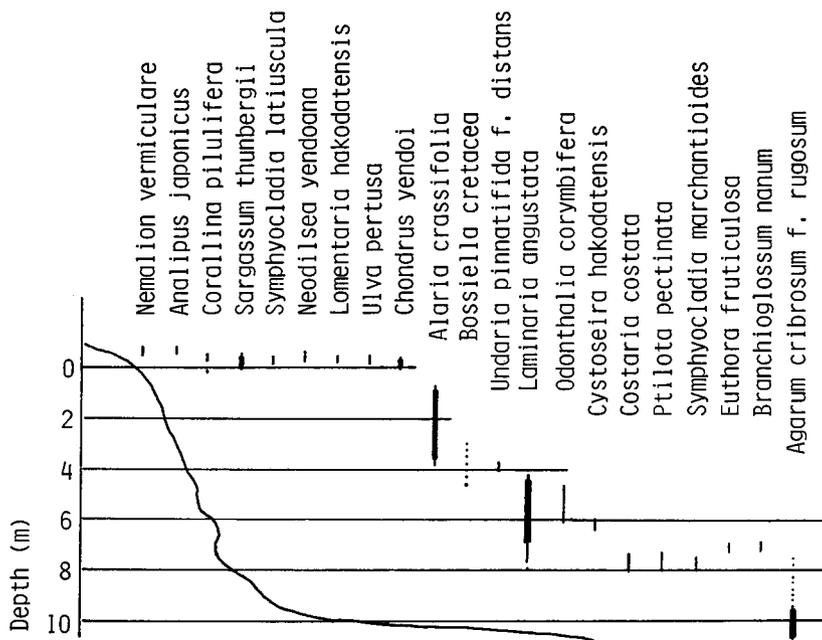


Fig. 42. Murooran (Loc. 22). Profile of the vertical distribution in the subtidal zone at Charatsunai (September 19, 1968).

Laminaria angustata in the lower portion. *Polysiphonia senticulosa* sometimes formed a narrow belt above the *Alaria* belt. On rocks in the inner area of the terrace *Gloiopeltis furcata*, *Pelvetia wrightii* and *Fucus evanescens* were dominant. *Rhodomela larix*, *Phyllospadix iwatensis* and *Ulva pertusa* occurred abundantly in flat shallow pools.

Subtidal zone: The profile of the vertical distribution is shown in Fig. 42.

The subtidal vegetation in this area was characterized by three major belts, namely the *Alaria crassifolia* belt, the *Laminaria angustata* belt and the *Agarum cribrosum* f. *rugosum* belt. The lower intertidal zone located at the head of a terrace was mainly occupied by *Sargassum thunbergii* and *Chondrus yendoi*. *Alaria crassifolia* formed a belt between depths of about 1 m and 4 m in which only *Bossiella cretacea* was recorded as undergrowth. At a depth of 4 m a few *Undaria pinnatifida* f. *distans* were observed. The upper portion of this plant had already been worn away by September. The area between the depths of 4.5 m and 7 m was dominated by *Laminaria angustata* which occurred between 4 m and 8 m. In this *Laminaria* belt, *Odonthalia corymbifera* and *Cystoseira hakodatensis* were also found. At about 8 m depth *Costaria costata*, *Ptilota pectinata*, *Symphyclocladia marchantioides*, *Euthora fruticulosa* and *Branchioglossum nanum* were found. *Agarum cribrosum* f. *rugosum* dominated the bottom below 10 m. The bottom below about 15 m changes to sand.

23. Shirikishinai

Shirikishinai (41°45'N., 141°05'E.) is located at the south-east tip of the Oshima Peninsula in southern Hokkaido. The coast is affected by the warm Tsugaru Current in summer, but it is affected by the cold Kurile Current in winter. The surface sea water temperature rises to 21°C in summer and falls to 2.7°C on the average in February. This coastline is mostly irregular rocky cliffs with a short terrace towards the sea. The area investigated consists of rugged rocky terrace with shallow pools and small crevices. From the outer edge of the terrace the slope drops steeply, and successive subtidal cliffs descend to a depth of 8 m, from which a relatively flat bottom with boulders declines gradually. Intertidal observations were made on a rocky slope of a crevice open to the sea, and subtidal investigation was carried out on a subtidal cliff down to 8 m on September 8, 1966.

The profile of the vertical distribution is shown in Fig. 43.

Intertidal zone: The area is semi-exposed to wave action because the crevice faces the open sea. A small amount of *Gloiopeltis furcata* and *Pelvetia wrightii* occurred in the upper region. In the small shallow pools,

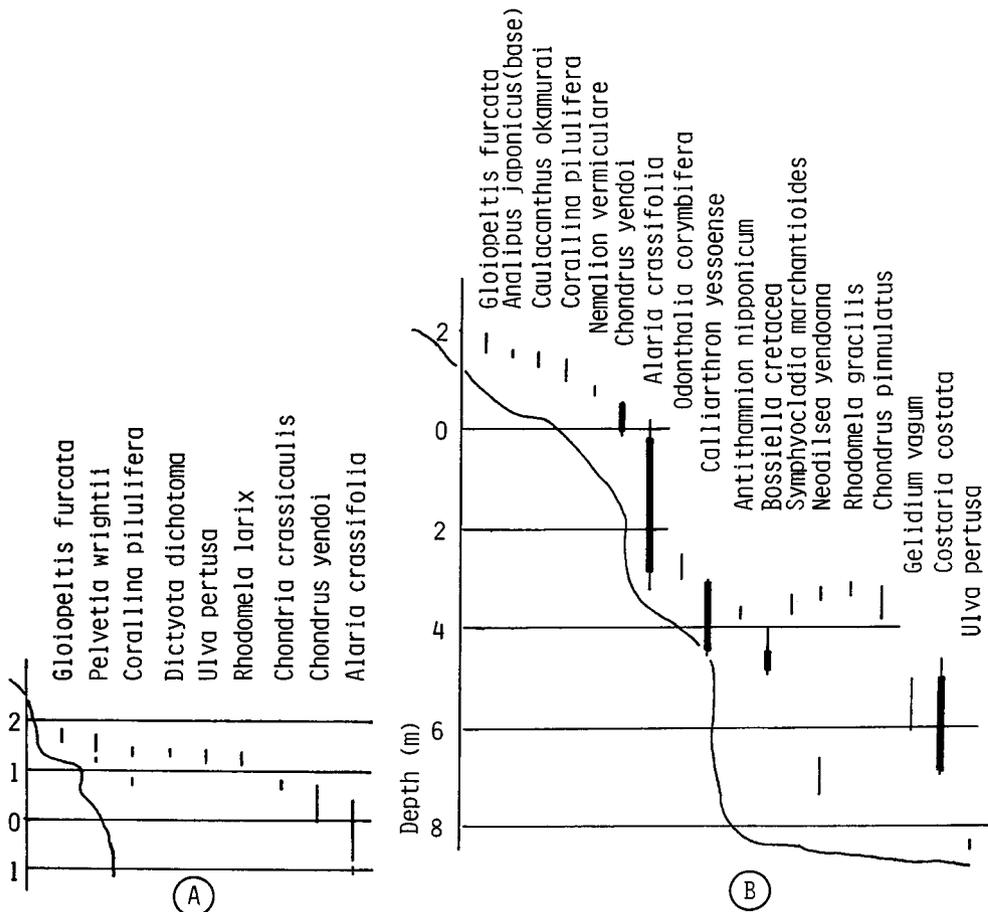


Fig. 43. Shirikishinai (Loc. 23). Profile of the vertical distribution in the intertidal (A) and subtidal zone (B) (September 8, 1966).

Dictyota dichotoma, *Ulva pertusa*, and *Rhodomela larix* occurred relatively abundantly. *Chondria crassicaulis* occurred on the edge of rocks. *Chondrus yendoii* and *Alaria crassifolia* dominated in the lower intertidal and in the uppermost part of the subtidal zone.

Subtidal zone: The subtidal vegetation of the area was characterized by four major belts, namely the *Alaria crassifolia* belt, the *Calliarthron yessoense* belt, the *Bossiella cretacea* belt and the *Costaria costata* belt. *Alaria crassifolia* formed a distinct belt from the lower intertidal zone down to about 3 m. *Calliarthron yessoense* occurred between depths of 3 m and 4.5 m with some *Antithamnion nipponicum* and *Symphycloadia marchan-*

tioides on its thallus. The *Bossiella cretacea* belt was very narrow. The zone between 5 m and 7 m was dominated by *Costaria costata* mixed with *Gelidium vagum* and *Neodilsea yendoana*. On the bottom at 8 m, *Ulva pertusa* was found relatively abundantly.

The vegetation observed may not be the typical vegetation of this coast, because two larger brown algae, *Laminaria japonica* and *Kjellmaniella crassifolia*, which are confirmed as occurring on this coast, were not observed.

V. Discussion

General discussion of the vegetation in Hokkaido

The vegetation in the subtidal zone of Hokkaido has scarcely been investigated except for some of the commercial algae, although the occurrence of certain subtidal algae has been known from cast ashore plants. In this study, an attempt was made to observe subtidal algae in their natural state, and to elucidate zonation patterns based on species forming distinct belt in the intertidal and the subtidal zone. However, since the localities selected for investigations were insufficient in number to cover the total coastline of Hokkaido, some algae forming significant communities previously reported were not found. Therefore, before going further, the occurrence and distribution of several noteworthy species previously reported and recorded in this study are discussed here.

Distinct belts of *Hizikia fusiformis* and *Ishige okamurai*, characteristic species to the warm current, were recorded at Matsumae in southwestern Hokkaido. Concerning to the distribution of *Hizikia fusiformis*, FUKUHARA (1959 a) stated that the northern limit of this species was at Benkei-misaki near Suttsu on the Japan Sea coast, and the plants found there were very small compared with those at Matsumae or Esashi on the southern coast. ATOBE and SAITO (1974) reported *Hizikia* from Hakodate Bay. YAMAMOTO (1965) reported the occurrence of *Ishigo okamurai* from Matsumae and Shirakami-misaki in May. He noted that it disappeared in summer. In this investigation, this species was accordingly found in April but not in June. In the subtidal zone at Matsumae, *Laminaria religiosa* was not observed in the area studied although its occurrence has been reported (HASEGAWA, 1959).

At Matsumae-Kojima, Y. YAMADA (1942) and HASEGAWA (1951) reported many interesting species which usually occur only in the warm Honshu district, such as *Ecklonia*, *Caulerpa*, *Padina*, *Hydroclathrus*, *Dilophus*, *Pachydictyon*, *Prionitis*, *Plocamium*, and others. They stated that the habitats

of these warm current species in very deep areas of 30~40 m in depth. K. SAITO *et al.* (1974 a), investigated the habitat of useful seaweeds at Kojima and reported *Ecklonia* as occurring between depths of zero and 4 m. In the present observations, this species was also observed in the upper subtidal zone. Many of the species mentioned as having deeper habitats by Y. YAMADA and HASEGAWA were observed on relatively shallow bottoms above the depth of 10 m in this study. Both Matsumae and Matsumae-kojima are regarded as being in a special temperate zone in Hokkaido based on the occurrence of marine algae there.

From the area near Shakotan Peninsula and Oshoro, INAGAKI (1933) made a taxonomic study of red algae from Oshoro Bay; TOKIDA and MASAKI (1954) reported a list of marine algae from Oshoro; FUNANO and HASEGAWA (1964) studied the seasonal succession of the *Gloiopeltis furcata* and *Chondrus yendoi* communities at Oshoro. Judging from their statements, the main algal belts observed in a year at the innermost part of the bay are of *Gloiopeltis furcata*, *Corallina pilulifera* and *Chondrus yendoi*, although *Chondrus yendoi* was not recorded in the area observed in the present study. Few observation have been made on the subtidal marine algae near Shakotan Peninsula and Oshoro. (I. YAMADA, 1972). The most interesting alga observed in the subtidal zone on this coast was *Dictyopteris divaricata*. This species occurs not only in the intertidal zone, but also in the deeper zone below *Laminaria* or *Undaria* as the most common alga along the Japan Sea coast of Hokkaido. In the deeper area at Yakishiri, Rebun and Rishiri Islands plants of *Agarum* usually dominate, however, in the area near the Shakotan Peninsula, or Oshoro *Agarum* community was not found. Therefore, the *Dictyopteris* community appears to be unique to this region. Small red algae on *Mytilus* collected from subtidal zone at Oshoro were noticed. *Pleonosporium pinnatum* reported here is a first record for Hokkaido.

From Yakishiri Island, K. SAITO *et al.* (1974 b) reported the occurrence of *Codium adhaerens* in the subtidal zone although this species was not found at Yakishiri and Teuri Islands during the present investigations. The occurrence of this species in the northern area of Hokkaido was first reported by FUKUHARA (1959 b) from Todo-jima of Rebun Island. Recently Y. SAITO (1972) noted the occurrence of *Codium adhaerens* in Oshoro Bay at a depth of 1 or 2 m. Therefore, this species may have a wide distribution on the Japan Sea coast. From Rishiri Island, KANEKO and NIIHARA (1970) reported 128 species of marine algae in which *Derbesia marina* and *Schizoseris* sp. (*S. minima* KANEKO et MASAKI, 1973) were first records for Hokkaido. They also pointed out that the flora of this island showed a similarity to that of

Oshoro, and that only two species, *Pelvetia wrightii* and *Odonthalia corymbifera*, are true cold current species not recorded at Oshoro. Concerning the distribution of *Fucus evanescens*, TOKIDA (1954) reported its occurrence on both Rishiri and Rebun Islands. However, this species was not recorded on Rishiri by KANEKO and NIIHARA (1970), nor on either island in this study. Therefore, in this paper this species is considered to be absent on these two islands although there is the possibility of a rare occurrence. In the deeper areas of Rishiri and Rebun Islands *Agarum cribrosum* f. *rishiriense* occurred abundantly. I. YAMADA (1974) made a taxonomic study of *Agarum* and referred to the distribution of this species as being endemic to the coasts of both Rishiri and Rebun Islands, on the other hand, *A. cribrosum* f. *yakishiriense* occurred only on the coasts of both Yakishiri and Teuri Islands. The environmental factors on these isolated two groups of islands have not been investigated. The distribution of *Laminaria* is also noticed. *Laminaria japonica* var. *ochotensis* is distributed along the Japan Sea coast north of the Shakotan Peninsula and on the Okhotsk Sea coast (HASEGAWA, 1959), and it occurs abundantly on the coasts of Rishiri and Rebun Islands. However, this species has not been reported from Teuri and Yakishiri Islands which are near Rishiri. *Laminaria religiosa* occurs commonly on the coasts of Yakishiri and Teuri Islands. Further investigations on the subtidal marine algae of these isolated islands is needed.

On the Okhotsk Sea coast few observations have been made, because the coastline is mostly sand except for Sôya-misaki, Kitami-Esashi, Saruru, Abashiri and west coast of Shiretoko peninsula. IWAMOTO (1960) reported 62 species of marine algae from Lake Saroma. The lake is brackish and the substrata are mostly sand or shell. Therefore, the species reported are abundant in characteristic plants to this lake such as *Enteromorpha*, *Monostruma*, *Punctaria* and others. TSUJI and KAKIUCHI (1974) reported some marine algae from Lake Notoro.

In the present observations, the community of *Laminaria japonica* var. *ochotensis* at Kitami-Esashi near the fisherman's harbor was insufficiently observed. Therefore, the vertical distribution of this species will not be discussed in detail here. However, according to fishermen it may occur in water shallower than 10 m. Judging from the plants cast ashore, it seems that dense communities of larger plants do not occur in the subtidal zone near Kitami-Esashi. In the intertidal zone at Kitami-Esashi, *Fucus evanescens* is observed. This species is usually associated with *Pelvetia wrightii* in the cold current region, but it has never been encountered in the area west of Kitami-Esashi. Therefore, the distributional limit of *Fucus* on the

western Okhotsk Sea coast may lie near this area.

In the eastern Hokkaido, YAMADA and TANAKA (1944 b) reported 48 species of marine algae from Shiretoko Peninsula. They (1944 a) also reported 125 species from Akkeshi on the Pacific coast. KAWASHIMA (1972) reviewed marine algae and developed a vegetational scheme for the Kushiro coast in which three major belts formed by *Analipus japonicus*, *Chondrus yendoi* and *Alaria praelonga* were recognized in the intertidal zone.

From Hidaka district, NAKAMURA, *et al.* (1955) mainly observed the habitat of *Laminaria angustata*, the zone of which was sometimes replaced by *Alaria crassifolia*. CHIHARA (1972) reported marine flora and communities of this coast, also. The zonation he recognized from the top down was *Gloiopeltis furcata*, *Porphyra* spp. — *Pelvetia wrightii*, *Fucus evanescens* — *Analipus japonicus* — *Chondrus yendoi* — *Phyllospadix iwatensis* — *Laminaria angustata*. He also suggested that the coastal water might be slightly affected by a warm current because of the occurrence of warm current species such as *Undaria pinnatifida* f. *distans* and *Acrosorium yendoi*.

In Uchiura Bay, SAITO and ATOBE (1970) studied the phytosociology of intertidal marine algae at Usujiri. They reported that *Rhodomela larix*, *Gloiopeltis furcata*, *Analipus japonicus* and *Phyllospadix iwatensis* were dominant on a natural rocky slope. Y. SAITO *et al.* (1971) also studied the algal communities on the vertical substratum facing several directions at Shirikishinai. They concluded that *Analipus japonicus* and *Corallina pilulifera* were "sun plants" and that *Ptilota pectinata* was a "shade plant". KAWABATA (1959) reported 108 species of marine algae from Shirikishinai with comments on their habitats. According to him, *Kjellmaniella crassifolia* and *Laminaria japonica* are most abundant in this area, however, the two species were not encountered in this study. Further investigations are needed here.

On Tsugaru Straits, ATOBE and SAITO (1974) studied the effect of wave action on algal zonation at Hakodate. According to them, the dominating species on exposed rocks are *Analipus japonicus*, *Corallina pilulifera* and *Symphyclocladia latiuscula*.

In addition, much vegetational data from Akkeshi, Hanasaki, Nemuro, Yoichi, and Muroran in Hokkaido are reported by TANIGUTI (1961). He concluded that the coasts of Hokkaido were characterized by the *Fucus evanescens*-*Laminaria angustata* var. *longissima* "association" on the Pacific coast, the *Analipus japonicus*-*Chordaria flagelliformis* "association" on the Okhotsk Sea coast, and the *Ulva pertusa*-*Laminaria religiosa* "association" on the Japan Sea coast.

Patterns of the vertical distribution

The pattern of the vertical distribution is considered on the basis of data from the open coast at each locality, because there were few sheltered places being representative of the local vegetation, and because sheltered places has much complicated environmental factors disturbing natural vegetation.

The patterns in each locality investigated are outlined below. These patterns are made on the basis of the main zone of each belt. A demarcation between the intertidal and subtidal is shown with an oblique line. The *Chordaria* belt occasionally occurs in both the lower intertidal and uppermost subtidal zone, in this case it is inserted between two oblique lines. Belts indistinctly observed, or reported by others were placed in parentheses.

Japan Sea Coast

1. Matsumae: *Gloiopeltis*—*Analipus japonicus*—*Corallina*—*Hizikia*/*Sargassum sagamianum* var. *yezoense*—*Undaria* (*Laminaria religiosa*, *L. japonica*)—*Desmarestia viridis*, *Dictyopteris*.

2. Matsumae-Kojima: *Gloiopeltis*—(indistinct)/*Ecklonia* (*Undaria*, *Laminaria japonica*)—*Prionitis*—*Acrosorium* sp.—*Dasya*—*Laminaria japonica*.

3. Kamui-misaki and Oshoro: *Gloiopeltis*—*Analipus japonicus*—*Corallina*—(*Chondrus*)/*Laminaria religiosa*—*Undaria*—(*Costaria*)—*Dictyopteris*, *Dasya*.

4. Yakishiri Island: *Gloiopeltis*—*Corallina*—*Chondrus*/*Laminaria religiosa*—*Undaria*—*Agarum cribrosum* f. *yakishiriense*—(*Dictyopteris*, *Dasya*).

5. Rishiri and Rebun Islands: *Gloiopeltis*—(*Analipus*)—(*Pelvetia*)—*Chondrus*—(*Corallina*)/*Laminaria japonica* var. *ochotensis*—*Undaria*—*Dictyopteris*, *Dasya*, *Codium adherens*—*Agarum cribrosum* f. *rishiriense*.

Okhotsk Sea Coast

6. Kitami-Esashi: *Gloiopeltis*—*Pelvetia*—(*Fucus*)—*Chondrus*—(*Chordaria flagelliformis*)/*Costaria*—*Hypophyllum*—(*Laminaria japonica* var. *ochotensis*)—*Champia*.

7. Utoro: *Gloiopeltis*—*Analipus japonicus*—(*Pelvetia*, *Fucus*)—*Analipus* sp.—*Corallina*—(*Chondrus*)/*Chordaria flagelliformis*—.....

Nemuro Straits

8. Shiretoko-misaki and Moireushi: *Gloiopeltis*—*Pelvetia*—*Fucus*—*Analipus japonicus*—*Analipus* sp.—*Chordaria flagelliformis*/*Alaria* sp.—*Laminaria diabolica*—*Agarum cribrosum* f. *rugosum*.

9. Rausu: *Gloiopeltis*—*Pelvetia*—*Fucus*—*Analipus japonicus*—*Chondrus*/*Chordaria flagelliformis*—*Phyllospadix*—*Costaria*—*Laminaria diabolica*, *L. sacchalinensis*.

10. Nemuro: *Gloiopeltis*—*Pelvetia*—*Fucus*—*Analipus*—*Chondrus*/*Chordaria flagelliformis*/*Kjellmaniella gyrata*—*Costaria*—*Agarum cribr osum* f. *rugosum*—(*Congregatocarpus*, *Nitophyllum*, *Rhodymenia*, *Tokidaea*, *Pterosiphonia*).

11. Notsukamappu: *Gloiopeltis*—*Pelvetia*—*Corallina*—*Fucus*/*Rhodome la*/*Phyllospadix*—...

12. Nosappu-misaki: *Gloiopeltis*—*Analipus*—*Chondrus*—*Corallina*/*Chordaria flagelliformis*/*Kjellmaniella gyrata*—*Laminaria angustata* var. *longissima*—(*Laminaria diabolica*)—*Agarum cribr osum* f. *rugosum*—(*Turnerella*).

Pacific coast

13. Hanasaki: *Gloiopeltis*—*Analipus*—*Pelvetia*—*Chondrus*/*Chordaria flagelliformis*/*Alaria praelonga*—*Laminaria angustata* var. *longissima*—(*Ptilota*, *Turnerella*, *Congregatocarpus*, *Constantinea*, *Odonthalia*).

14. Akkeshi: *Gloiopeltis*—*Analipus*—*Pelvetia*—*Corallina*—*Chondrus yendoi*—/*Chordaria flagelliformis*/*Alaria praelonga*—*Laminaria angustata* var. *longissima*—*Agarum cribr osum* f. *cribr osum*—*Arthrothamnus bifidus*.

15. Kushiro: /*Alaria praelonga*/—*Laminaria angustata* var. *longissima*—*Laminaria coriacea*—(*Agarum cribr osum* f. *cribr osum*)—*Constantinea*.

16. Erimo-misaki: *Gloiopeltis*—*Analipus*—(*Pelvetia*, *Fucus*)—*Chondrus yendoi*/*Alaria crassifolia*—*Laminaria angustata*.

17. Muroran: *Gloiopeltis*—*Analipus*—*Pelvetia*—(*Fucus*)—*Corallina*—*Chondrus yendoi*/*Alaria crassifolia*—*Laminaria angustata*—(*Undaria*)—*Agarum cribr osum* f. *rugosum*.

18. Shirikishinai: *Gloiopeltis*—*Analipus*—*Corallina*—*Chondrus*/*Alaria crassifolia*—*Calliarthron yessoense*—*Costaria*—(*Laminaria japonica*, *Kjellmaniella crassifolia*).

Nine taxa from the intertidal and twenty-nine taxa from the subtidal are selected to characterize these patterns. These algae are mostly perennial plants or ones which grow densely from year to year. Among these thirty-eight taxa, twenty-seven are Phaeophyta and eleven are Rhodophyta. The intertidal representatives have relatively wide ranges in horizontal distribution, but the subtidal ones are found in relatively restricted areas of Hokkaido (Table 4). It is also noticed that many of the subtidal representatives belong to the Laminariales.

Intertidal zonation on Hokkaido is composed essentially of *Gloiopeltis furcata*, *Analipus japonicus*, *Corallina pilulifera* and *Chondrus yendoi*. In addition to these zones, the coasts except for the Japan Sea coast and the western coast of Tsugaru Straits are characterized by the occurrence of *Pelvetia wrightii* and *Fucus evanescens*. Further, the Okhotsk Sea coast, Nemuro Straits, and the east coast of Kushiro are characterized by the occurrence of a *Chordaria flagelliformis* belt between the intertidal and subtidal zones. Nemuro Straits and Utoro are also characterized by the occurrence of *Analipus* sp. The coast near Matsumae is characterized by the occurrence of *Hizikia fusiformis* instead of *Chondrus yendoi* in this area. Thus, six patterns of vertical distribution are recognized in the intertidal zone along the coast of Hokkaido (Table 4).

Likewise, eleven patterns of vertical distribution are recognized in the subtidal zone along the coast of Hokkaido as shown in Table 4. The basic patterns in the subtidal zone are roughly demonstrated as follows; (1) *Ecklonia*—red algae—(*Laminaria*), (2) *Laminaria religiosa*—*Undaria*—*Dictyopteris*—(*Agarum*), (3) *Alaria*—*Laminaria*—*Agarum*—(*Arthrothamnus*), (4) *Kjellmaniella*—(*Costaria*)—(*Agarum*)—red algae. These four basic patterns are further divided according to characteristic species.

The intertidal representatives have wider ranges in horizontal distribution than the subtidal ones, as mentioned before. Among nine intertidal representatives, four species, *Gloiopeltis furcata*, *Analipus japonicus*, *Corallina pilulifera*, and *Chondrus yendoi*, are common to the coasts of Hokkaido, whereas among twenty-nine subtidal representatives, only two species, *Costaria costata* and *Desmarestia viridis* are common to these coasts, although they do not form distinct communities regularly (Table 4). These may suggest that the intertidal species forming distinct belt can survive under various conditions, on the other hand, the subtidal species occur in a defined condition. Therefore, the subtidal algae may be more sensitive to the influences of the warm and cold currents than the intertidal algae.

The coast of Hokkaido can be divided horizontally into several sections on the basis of these patterns of vertical distribution of marine algae. However, there is a difference in the intertidal and subtidal divisions as shown in Table 4 and Fig. 44. In the case of the intertidal, the coast is divided into seven sections by six vertical distribution patterns, namely (1) the coast from Hakodate to Benkei-misaki in Suttso via Matsumae, (2) from Benkei-misaki to Noshappu-misaki in Wakkanai and Rishiri Island, (3) from Noshappu-misaki and Rishiri Island to Kitami-Esashi, (4) from Kitami-Esashi to Utoro, (5) from Utoro to Nosappu-misaki on the Nemuro Peninsula, (6)

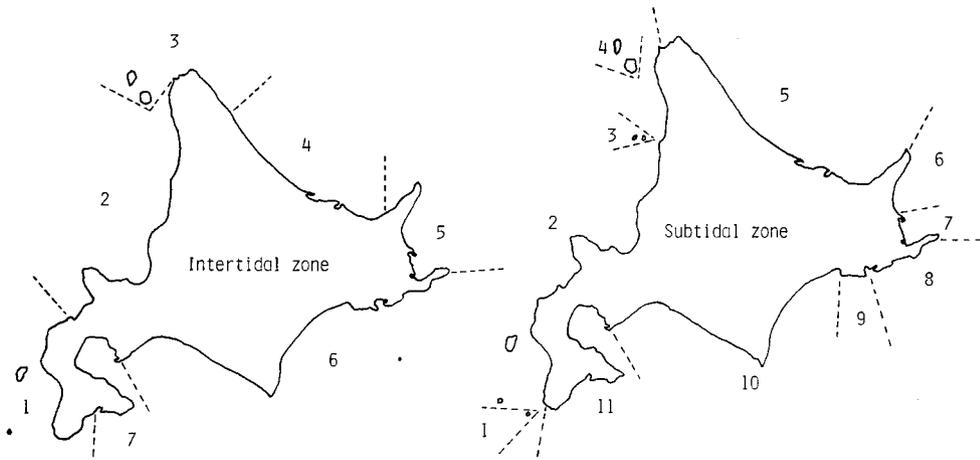


Fig. 44. Geographical sections, seven in the intertidal and eleven in the subtidal zone, based on the patterns of vertical distribution of certain marine algae forming the main belts or communities on the coasts of Hokkaido.

from Nosappu-misaki to Muroran, and (7) from Muroran to Hakodate. On the other hand, the subtidal zone on the coast of Hokkaido is divided into eleven sections by eleven patterns, namely, (1) Matsumae-Kojima, (2) from Hakodate to Noshappu-misaki, (3) Yakishiri and Teuri Islands, (4) Rishiri and Rebun Islands, (5) from Noshappu-misaki to Shiretoko-misaki, (6) from Shiretoko-misaki to Nemuro-Shibetsu (indistinct), (7) from Memuro-Shibetsu to Nosappu-misaki, (8) from Nosappu-misaki to Akkeshi, (9) from Akkeshi to Kushiro, (10) from Kushiro to Muroran, and (11) from Muroran to Hakodate.

OKAMURA (1928, 1931) proposed four distributional areas on the coast of Hokkaido, namely (1) from Nosappu-misaki to Erimo-misaki, (2) from Erimo-misaki to Muroran, (3) south of Muroran, and (4) from Tsugaru Straits to Nosappu-misaki via Sôya-misaki and Shiretoko-misaki. FUKUHARA (1968) divided the coast of Hokkaido into ten sections on the basis of the distribution of *Porphyra*. In addition to OKAMURA's areas, FUKUHARA drew boundary lines at Shirakami-misaki, Era, Rishiri and Rebun Islands, Shiretoko-misaki, Onneto near Nemuro, Usu, and Esan-misaki near Shirikishinai. The four boundary lines at Rishiri and Rebun Islands, Shiretoko-misaki, Nemuro, and Shirikishinai proposed in this paper agree well with FUKUHARA's.

A scheme of the main representatives of intertidal and subtidal vegetations around Hokkaido is summarized in Fig. 45.

The scheme also shows the horizontal distribution of the representative species. However, relatively small algae such as *Dictyopteris divaricata*

such as *Congregatocarpus pacificus*, *Cystoseira crassipes*, *Callophyllis rhyncocarpa*, *Callymenia ornata*, *Euthora fruticulosa* and *Nitophyllum yezoense* occur only in areas affected by cold currents. On the other hand, several species occurring in the warm current area in Honshu are also found in Hokkaido. *Codium adhaerens* occurs in deep areas on the Japan Sea coast. *Dictyota dichotoma* is also widely distributed on the coasts except for the Pacific coast east of the Hidaka district. *Pleonosporium pinnatum* collected from the subtidal zone at Oshoro is also interesting in its distribution. The plant is regarded as a warm current species because the type specimen was collected from Izu on the middle part of Honshu by SEGAWA (1936). The occurrence of *Derbesia marina* was reported from Rishiri Island by KANEKO and NIIHARA (1970). This species was also found in the deep areas at Shiretoko-misaki and Moireushi in this study. This occurrence indicates that the coast of Shiretoko Peninsula is affected by the warm current. *Syringoderma australe* found for the first time at Rishiri Island is a very interesting alga in that the distribution pathway from the Antarctic Sea is not obvious. These rare species in the deep zone will be further investigated later.

Comparisons of subtidal vegetation patterns with those in other northern regions

There is little data on the subtidal vegetation of Japan. In the southern area, YOSHIDA (1961) and YOSHIDA *et al.* (1963) studied a *Sargassum* community. KIDA (1964, 1965, 1974), TANAKA (1967), and TANAKA and ITONO (1969 a, b) reported outlines of the marine algal vegetation from several places. On the northern Honshu, YOSHIDA (1973) investigated marine algal vegetation at an islet in Matsushima Bay. According to him, the upper subtidal zone between the depths of 0 and 5 m is occupied by a community of large brown algae dominated by *Eisenia bicyclis*, and small herbaceous algae such as *Acrosorium flabellatum*, *Plocamium telfairiae* and *Pikea californica* occur at 6~8 m depth.

On the Kurile Islands, NAGAI (1941) recognized several "formations" in the upper subtidal zone. The *Laminaria* "formation" on the western and southwestern coast of Kunashiri Island in the upper temperate district is made up of *L. sacchalinensis*, *L. ochotensis*, *L. diabolica*, *Sargassum horneri*, etc. In the lower boreal district, the *Kjellmaniella gyrata* "formation" and the *Laminaria* "formation" made up of *L. coriacea*, *L. angustata* and *L. angustata* var. *longissima* are reported. In the upper boreal district, *Alaria fistulosa* and *Arthrothamnus bifidus* "formations" also contain many characteristic species of the northern Kurile Islands.

From the Okhotsk Sea, VOZZHINSKAYA (1966) described the marine algal vegetation in the intertidal and subtidal zones. She summarized the main belts of the algae as *Urospora*, *Gloiopeltis*, *Analipus*, *Corallina*, *Fucus*, *Porphyra*, Diatoms, *Halosaccion*, *Lessonia*, *Laminaria*, *Alaria* and some red algae. Judging from her description and a figure in the south-west coast of Kamtschatka, the zonation pattern on an open shore is probably as follows; *Gloiopeltis* — *Halosaccion* — *Porphyra* (*P. tasa*) — *Alaria praelonga*, *A. fistulosa*/*Laminaria longipes* — *Streptophyllum* — *Desmarestia* — *Laminaria subsimplex* — *Ptilota asplenioides*. VOZZHINSKAYA and BLINOVA (1970) collected subtidal marine algae by diving and trawls on the coast of the central Kamtschatka in the Okhotsk Sea and recognized underwater forest with *Laminaria gurjanovae*, *L. appressirhiza*, *Alaria praelonga*, and others. In the north western part of the Okhotsk Sea the zonation is *Urospora*, *Ulothrix* — *Gloiopeltis* — *Halosaccion* — *Porphyra* (*P. ochotensis*) — *Laminaria* (*L. grujanovae*, *L. saccharina*) — *Lessonia*/*Alaria* (*A. crassifolia*, *A. dorichorihacyis*) — *Chondrus crispus*, *Ptilota* — *Tichocarpus*, *Odonthalia*, *Desmarestia* — *Laminaria* (*L. subsimplex*, *L. taeniata*) — *Phycodryx* — *L. digitata* (VOZZHINSKAYA 1966).

VOZZHINSKAYA and SELITSKAYA (1970) reported the zonation, biomasses and density of marine algae on the coast of Shantar Island, and recognized distinct subtidal belts of *Lessonia laminarioides*, *Laminaria grujanovae* and *Cystoseira crassipes*.

On the western coast of the United States, NEUSHUL (1965) distinguished six major zones in the marine algal vegetation at La Jolla, California, namely upper, middle, lower intertidal and upper, middle, lower subtidal zones. If the upper subtidal and the lower intertidal are considered one zone, five zones are distinguished. On the La Jolla coast, *Macrocystis*, *Egregia*, *Hali-dryx* and *Sargassum* occur mainly in the upper subtidal zone, *Eisenia*, *Pterygophora*, *Agarum* and *Laminaria* in the middle, and *Maripelta*, *Phyllophora* and *Stennogramme* in the lower. NEUSHUL (1965) also recorded the subtidal vegetation on San Juan Island in Washington. He listed *Alaria*, *Nereocystis*, *Costaria*, *Laminaria* and *Agardhiella* in the upper subtidal zone, *Agarum cribrosum*, *A. fimbriatum*, and small algae in the middle subtidal zone, *Callophyllis*, *Agarum fimbriatum* and crustose algae in the lower subtidal zone.

On the eastern coast of the United States, LAMB and ZIMMERMANN (1964) described the subtidal vegetation on Cape Ann, Massachusetts. They recorded *Sacchoriza*, *Alaria*, *Chorda*, *Rhodomenia*, *Halosaccion*, etc. in the upper, a *Laminaria* belt in the middle at depths from 2 m to 12 m, and an

Agarum belt in the lower from 10 m to 20 m depth.

EDELSTEIN *et al.* (1969) observed north Atlantic subtidal vegetation at Halifax, Canada. They recorded a *Laminaria* — *Desmarestia* “association” occurring in the upper zone from 0 to 15 m deep, an *Agarum* — *Ptilota* “association” occurring below the depth of 10 m and a *Phyllophora* — *Polysiphonia* “association” occurring between 30~40 m. They recognized a tripartite subtidal vegetative zonation as a general feature of cold waters.

KAIN (1960) observed subtidal algae on the coast of Isle of Man, England. She also recognized three major subtidal zones. *Laminaria hyperborea* dominates from 0 to 6 or 7 m deep mixed with *Alaria*, *Dictyota*, *Delesseria*, etc. Below the *Laminaria* belt, *Saccorhiza* occurs for about 10 m downwards. Below this belt many small red algae occur.

From the Norwegian coast, JORDE and KLAVESTAD (1963), JAASUND (1965), and JORDE (1966) reported marine algal vegetation. According to JORDE and KLAVESTAD, *Acrosiphonia*, *Gigartina*, *Alaria*, *Himanthalia* and *Laminaria digitata* occur in the upper subtidal zone in exposed places, and *L. hyperborea* and *L. saccharina* occur in deep area down to 30 m. In sheltered areas, *Fucus vesiculosus*, *Ascophyllum nodosum* and *Fucus serratus* develop well in the upper subtidal zone, and in the zone below the depth of 2.5 m, *Dictyosiphon*, *Scytosiphon*, *Desmarestia* and others were recorded.

From the east coast of Sweden, WAERN (1952) described the subtidal vegetation in detail. Along this coast large marine plants were not recorded.

LÜNING (1970) reported the subtidal vegetation at Helgoland. According to him, the upper subtidal zone of 0.5 to 1.5 m deep is occupied by *Laminaria digitata* and *L. saccharina*, and that of 1.5 to 4 m is dominated by *L. hyperborea*, and the zone between 4 and 10 m in depth is inhabited by *Plocamium*, *Delesseria*, *Polysiphonia*, *Phyllophora*, *Ulva* and *Desmarestia*. In the zone from 10 to 12 m *Phyllophora* and *Audouinella* are recorded.

Thus, the pattern of subtidal vegetation of Hokkaido is very similar to those found on the coasts of the Pacific, the Atlantic, and the Okhotsk in that the zone is made up of three or four algal zones. The patterns in Hokkaido are also somewhat similar to those found on the north Atlantic coast of Canada and United States by the common occurrence of *Laminaria* and *Agarum* communities.

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VII. Summary

The benthic marine algal vegetation, mainly on the vertical distribution, in the intertidal and subtidal zones was investigated at twenty-three localities on the Japan Sea coast, the Okhotsk Sea coast, and the Pacific coast of Hokkaido from 1964 to 1970. Subtidal investigations were made by diving using Scuba down to a maximum depth of 25 m. The results are as follows.

1. The vertical distribution and vegetation of marine algae in each locality were described and shown in profiles (Figs. 9~43).

2. In order to characterize the patterns of the vertical distribution, the nine representative taxa for the intertidal and twenty-nine for subtidal were selected from the species forming main belt or community at exposed or semi-exposed shores.

3. After comparing the representative taxa, six patterns of vertical distribution were recognized in the intertidal zone and eleven patterns recognized in the subtidal (Table 4).

4. According to these patterns, the coast of Hokkaido is sectioned horizontally into seven areas for the intertidal zone and eleven for the subtidal (Table 4 and Fig. 44).

5. The six patterns in the intertidal zone are as follows: (1) *Gloiopeltis furcata* — *Analipus japonicus* — *Corallina pilulifera* — *Chondrus yendoi* —

Hizikia fusiformis on the south-west coast of the Japan Sea; (2) *Gloiopeltis furcata* — *Analipus japonicus* — *Corallina pilulifera* — *Chondrus yendoi* in the middle of the Japan Sea coast; (3) *Gloiopeltis furcata* — *Analipus japonicus* — (*Pelvetia wrightii*) — *Chondrus yendoi* — (*Corallina pilulifera*) — (*Chordaria flagelliformis*) on the coasts of Rishiri and Rebun Islands in the northern Japan Sea and on the coast from Noshappu-misaki of Wakkanai to Kitami-Esashi; (4) *Gloiopeltis furcata* — *Analipus japonicus* — *Pelvetia wrightii* — *Fucus evanescens* — *Corallina pilulifera* — (*Chondrus yendoi*) — *Chordaria flagelliformis* on the Okhotsk Sea coast and the Pacific coast of eastern Hokkaido; (5) *Gloiopeltis furcata* — *Analipus japonicus* — *Pelvetia wrightii* — *Fucus evanescens* — *Corallina pilulifera* — *Analipus* sp. — *Chondrus yendoi* — *Chordaria flagelliformis* on the coasts of Nemuro Straits; (6) *Gloiopeltis furcata* — *Analipus japonicus* — *Pelvetia wrightii* — *Fucus evanescens* — *Corallina pilulifera* — *Chondrus yendoi* on the Pacific coast of southern Hokkaido (Table 4 and Fig. 44).

Among the nine representative taxa, *Gloiopeltis furcata*, *Analipus japonicus*, *Corallina pilulifera*, and *Chondrus yendoi* form the belts commonly on all the coasts of Hokkaido. Whereas, *Hizikia fusiformis*, *Pelvetia wrightii*, *Fucus evanescens*, *Analipus* sp., and *Chordaria flagelliformis* are not present in some areas.

6. The eleven patterns in the subtidal zone are as follows: (1) *Ecklonia stolonifera*, (*Undaria pinnatifida* f. *distans*, *Laminaria japonica*) — *Prionitis patens* — *Acrosorium* sp. — *Dasya sessilis* — *Laminaria japonica* —··· on the coast of Matsumae-Kojima on the southernmost part of the Japan Sea coast; (2) *Laminaria religiosa*, (*Sargassum sagamianum* var. *yezoense*) — *Undaria pinnatifida* f. *distans* — *Dictyopteris divaricata*, (*Desmarestia viridis*, *Dasya sessilis*) on the Japan Sea coast except for isolated islands, and the western coast of Tsugaru Straits; (3) *Laminaria religiosa* — *Undaria pinnatifida* f. *distans* — *Agarum cribrosum* f. *yakishiriense* on the coast of Yakishiri and Teuri Islands; (4) *Laminaria japonica* var. *ochotensis* — *Undaria pinnatifida* f. *distans* — *Dictyopteris divaricata*, *Dasya sessilis*, *Codium adhaerens* — *Agarum cribrosum* f. *rishiriense* on the coasts of Rishiri and Rebun Islands; (5) (*Chordaria flagelliformis*) — *Costaria costata* — *Hypophyllum middendorffii* — (*Laminaria japonica* var. *ochotensis*) — *Champia parvula* on the Okhotsk Sea coast; (6) (*Chordaria flagelliformis*) — *Alaria* sp. — *Laminaria japonica* var. *ochotensis*, *L. diabolica* — *Agarum cribrosum* f. *rugosum* on the northern coast of Nemuro Straits; (7) (*Chordaria flagelliformis*) — *Kjellmaniella gyrata*, (*Phyllospadix iwatensis*) — *Costaria costata* — *Agarum cribrosum* f. *rugosum* — (red algae) on the south-

ern coast of Nemuro Straits; (8) (*Chordaria flagelliformis*) — *Alaria praelonga* — *Laminaria angustata* var. *longissima* — *Agarum cribrosum* f. *cribrosum* — *Arthrothamnus bifidus* on the coast from Nosappu-misaki to Akkeshi of the Pacific coast; (9) *Alaria praelonga* — *Laminaria angustata* var. *longissima* — *Laminaria coriacea* — (*Agarum cribrosum* f. *cribrosum*) — *Constantinea subulifera* on the coast from Akkeshi to Kushiro; (10) *Alaria crassifolia* — *Laminaria angustata* — (*Agarum cribrosum* f. *cribrosum*) on the coast from Kushiro to Murooran on the Pacific coast; (11) *Alaria crassifolia* (*Calliarthron yessoense*) — *Laminaria japonica* (*Kjellmaniella crassifolia*, *Laminaria angustata*) — (*Undaria pinnatifida* f. *distans*) — *Agarum cribrosum* f. *rugosum* on the coast from Murooran to Hakodate along the Tsugaru Straits.

In the subtidal zone, only two species among the twenty-nine representatives, *Costaria costata* and *Desmarestia viridis*, are common on all the coasts of Hokkaido, although they do not form distinct communities regularly.

7. A scheme showing the vertical and horizontal distribution of marine algae forming distinct belts around Hokkaido is summerized in Fig. 45.

8. Several species which were interesting with respect to horizontal distribution were recorded from subtidal zone; *Derbesia marina* at Shiretoko Peninsula, *Syringoderma australe* at Rishiri Island, *Euthora fruticulosa* at Shiretoko, Nemuro, and Akkeshi, and *Pleonosporium pinnatum* at Oshoro.

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