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Distribution of marine algae in the Japan Sea, with reference to the phytogeographical positions of Vladivostok and Noto Peninsula districts*

By

Setsuo FUNAHASHI**

Contents

Introduction

The present writer (1966, 1967, 1968) carried out the floristic studies on marine algae from Vladivostok and Noto districts of the Japan Sea. On the basis of those studies a need is felt to understand fully the distributional characteristics of marine algae in the Japan Sea as a whole, with emphasis on the location of these two districts from the point of view of phytogeography. Concerning this aspect of study, we have at hand eminent investigations of OKAMURA (1928, 1931, 1932). More than 30 years have already passed since he discussed the distribution of marine algae in the Japan Sea, and since additional reports and data are now available, it is the purpose of this paper to bring the knowledge up to date.

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* This is a part of a dissertation submitted for the degree of Doctor of Science in the Hokkaido University, and is dedicated to Professor Yositeru NAKAMURA on the occasion of his academic retirement with much appreciation for the friendly encouragement provided during my studies.

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TABLE 1. Main floristic studies concerned with marine algae of the Japan Sea

Coast	Author	Year	Number of* species
I Saghalien	TOKIDA, J.	1954	133
	ZINOVA, A. D.	1959	150
II Hokkaido	INAGAKI, K.	1933	69
	YAMADA, Y.	1942	62
	HASEGAWA, Y.	1954	110
	TOKIDA, J. and MASAKI, T.	1959	215
	YAMAMOTO, H.	1965	9
III Honshu	OKAMURA, K.	1893	34
	HIGASHI, M.	1936	236
	HIROHASHI, T.	1937	157
	TAKAMATSU, M.	1939	179
	ÔSHIMA, K.	1950	206
	IMAHORI, K. and SEARASHI, T.	1955	184
	SAITO, Y.	1956	135
	IKOMA, Y.	1956–57	96
	HIROSE, H.	1956	145
	NODA, M.	1960	204
	NODA, M.	1963	44
	KATO, K. and KATO, T.	1963	103
	KANAMORI, T.	1965	173
	FUNAHASHI, S.	1967	147
IV Korea	OKAMURA, K.	1915–17	114
	NODA, M. and KANG, J. W.	1964	69
	KANG, J. W.	1965	106
	NODA, M.	1966	120
	KANG, J. W.	1966	332
V Maritime Territory	ZINOVA, E. C.	1928	46
	ZINOVA, E. C.	1929	74
	ZINOVA, E. C.	1938	94
	ZINOVA, E. C.	1940	201
	ZINOVA, E. C.	1953	18
	ZINOVA, A. D.	1960	10
	FUNAHASHI, S.	1966	109
Whole Japan Sea	OKAMURA, K.	1900–02	6
	OKAMURA, K.	1907–12	137
	OKAMURA, K.	1916	171
	OKAMURA, K.	1936	367
	YENDO, K.	1907–18	68
	YAMADA, Y.	1930–44	20
	SEGAWA, S.	1956	160

* The number is calculated after the nomenclatural examination of specific names.

Historical sketch of the studies on marine algae of the Japan Sea

The marine algae of the Japan Sea is known in the literatures from floristic studies, monographical treatments and discussions on distribution. Floristic works in the Japan Sea are listed in chronological order according to the coasts of the area concerned (Table 1).

In Table 2, monographical works, in which marine algae from the Japan Sea are also mentioned, are enumerated in alphabetical order by

TABLE 2. Monographic studies concerned with the marine algae of the Japan Sea

Author	Taxon	Year	Number of species
FUKUHARA, E.	*Porphyra*	1963	5
INAGAKI, K.	Chordariales	1954, '58	22
MIKAMI, H.	Phyllophoraceae and Gigartinaceae	1965	15
NAKAMURA, Y.	*Rhodochorton*	1944	2
NODA, M.	*Spermothamnion*	1960	3
NODA, M.	*Monostroma*	1962	3
NODA, M.	*Porphyra*	1964	6
NODA, M.	*Wrangelia*	1964	3
NODA, M.	Dictyotaceae	1965	19
NODA, M.	Ceramiaceae	1967	28
NODA, M.	Rhodomelaceae	1967	41
OHMI, H.	*Gracilaria* and *Gracilariopsis*	1958	3
SAKAI, Y.	*Cladophora*	1964	9
SEGI, T.	*Polysiphonia*	1951	15
TANAKA, T.	*Galaxaura*	1936	1
TANAKA, T.	*Hypnea*	1941	5
TANAKA, T.	*Bangia*	1950	2
TANAKA, T.	*Erythrotrichia*	1951	3
TANAKA, T.	Protoflorideae	1952	21
UEDA, S.	*Porphyra*	1932	8
UMEZAKI, I.	Blue-green algae	1961	61
YAMADA, Y.	*Laurencia*	1931	3
YENDO, K.	Corallinae	1902	11
YENDO, K.	Fucaceae	1907	24

names of the authors together with taxonomic groups treated, year of publication and number of species concerned.

Important contributions which discuss geographical distribution of marine algae in the Japan Sea are those of OKAMURA (1928, 1931, 1932), SEGAWA (1956), HIROHASHI (1937), TOKIDA (1953, 1954), A. D. ZINOVA (1960), NODA (1963, 1966, 1967), KANG (1966) and FUNAHASHI (1968).

OKAMURA (1932) studied geographical distribution of 3794 species of marine algae reported from Pacific waters until April, 1931, and proposed that the Pacific Ocean would be divided into 5 regions: i.e. 1) Japan, 2) the China Sea, 3) the Bering Sea, 4) the America, 5) the Australia, and 6) the Malay Archipelago, 7) Polynesia. This division has been generally accepted by phycologists up to the present.

On the other hand, in 1928 and 1931 he divided the coasts of Japan and its vicinity including Kuriles, Formosa and Korea into following five sections, namely 1) North Kuriles—Kinkwazan Island, Miyagi Pref., 2) Kinkwazan Isl.—Oshima Island, Miyazaki Pref., 3) Oshima Isl.—Cape Nomazaki, Kagoshima Pref., 4) Cape Nomazaki—west coast of Kyushu—the Japan Sea coast of Honshu—Tsugaru Strait, and 5) Tsugaru Strait—Sôya Strait—Cape Nosappu, Nemuro Prov., Hokkaido. Oceanic currents were considered by him as one of the major factors controlling the distribution of marine algae. Of these, only the 4 and 5 Sections have direct bearing on this study.

OKAMURA's thoughts on the distribution of marine algae in the Japan Sea can be summarized as follows. The Japan Sea is comprised in the Japan Region including the Yellow, the East China and Okhotsk Seas. The Japan Sea coast could be divided into 3 zones mentioned below from distributional features of marine algae.

1) Arctic and subarctic zones: West coast of Saghalien, and northern east coast of Korea between Wonsan and mouth of Tumen River.

2) Intermediate zone between subarctic and temperate Zones: West coast of Hokkaido.

3) Temperate zone: West coast of Honshu, and southern east coast of Korea between Wonsan and Pusan.

In 1927 he mentioned that there were several species of seaweeds peculiar to the Japan Sea coast. No reference was made by him to Maritime Territory of USSR (Siberia).

SEGAWA (1956) additionally proposed to subdivide the west coast of Honshu (Ura-nihon) into 3 parts, namely, north, middle and south.

HIROHASHI (1937) expressed his opinion on the distribution of marine algae in the islands lying along the west coast of north Honshu. Tobi-

shima, Awashima and Sado Islands were concerned here.

TOKIDA (1953) explained the distribution of marine algae in Sôya (La Perouse) Strait. In his work titled "Marine Algae of Southern Saghalien" (1954), he classified the coast of southern Saghalien into 5 sections according to conditions of water temperature. His sections I and V comprised the west coast of Saghalien facing the Japan Sea. Section I corresponded to the coast north of Muitomari and Kaibato Island, and section V was cold water region near Cape Nishinotoro. Section I is equivalent to north temperate zone with 15–20°C isotherms in August, while section V to upper boreal zone with 5–10°C isotherms, according to the classification introduced by Setchell (1915).

A. D. ZINOVA (1960) discussed the distribution of marine algae along the shores of southern Saghalien and Kurile Islands based on recently collected materials and published literature.

NODA (1963) compared the marine floras of the west coast of Sado Island (about 38° N. lat.) and Honshu, after surveying marine algae from Sado. He stated that 30 species had their northern limits of distribution in this Island. Then he (1966) surveyed marine algae of Korea, and showed some resemblance of flora to those of the Pacific and the Japan Sea coasts of Honshu. More recently, he (1967) stated that about 890 species of marine algae were reported from the Pacific coast of Japanese Islands, and 590 species from the Japan Sea coasts, and that among these algae about 370 species were common to both these coasts.

KANG (1966) carried out a study on the flora and distribution of marine algae of Korea. He made a revision of sectioning the coast of Korea by OKAMURA (1913, 1928). The coast of Korea was subdivided by him into 5 sections according to conditions of temperatures, oceanic currents and others. Section I (northeastern coast), II (southeastern coast) and a part of section III (south coast) are facing to the Japan Sea. On the east coast of Korea, the East Korea Warm Current usually reaches the area between Ulrungdo Island and Chumunjin or Chukbyeon in winter months. Southern limit of the North Korea Cold Current also lies in nearly the same area. He confirmed that this transition area coincided with the southern limits of distribution of boreal species. On the east coast of Korea, temperate species predominates over boreal species. It was shown that the characteristics of the marine flora of this coast were similar to those of Hokkaido and north Honshu, because of the stronger effect of the Tsushima Warm Current than the Cold Current.

FUNAHASHI (1968) compared the floras of Vladivostok and Noto Penin-

sula, and made a comparison of the growth and period of reproduction on the species common to both areas.

Topography and hydrography of the Japan Sea

The name of the Japan Sea was first introduced by A. J. DE KRUNSENSTERN, Russian navigator, in his Chart appearing in 1815.

The Japan Sea is one of the marginal seas lying in the north Pacific Ocean. Its western border is the continent of Asia; on the east it is separated from the Pacific by aaghalien, Hokkaido, and Honshu Islands. The lands on the east side of the Japan Sea show an uneven coastline with peninsulas and embayments, and there are several islands along the coast, such as Rebun, Rishiri, Okushiri, Tobishima, Sado, Oki Islands. On the contrary, the west side along Korea and Maritime Territory of USSR shows comparatively monotonous coastline, with only Takeshima and Ulrungdo Islands. The Japan Sea is connected with the East China Sea by the Tsushima Strait in the south-west; in the north-east by the Tsugaru Strait with the Pacific; and in the north by Sôya and Tartary Straits with Okhotsk Sea. The straits are shallow, but the Japan Sea is a deep basin that slopes away from the Japanese coast more gently than from the mainland coast of Asia. It has a surface area of 1,300,000 km^2, six times as large as Honshu, and a volume of 2,110,000 km^3. An average depth is 1543 m; the greatest measured depth, 3610 m, is in the eastern part.

Although the basic hydrographic regime of the Japan Sea is influenced by the deep basin and by shallow straits from the Pacific Ocean, the East China and the Okhotsk Seas, its surface layer has the features connected with those of the marginal seas. Fig. 1 illustrates a scheme of oceanic currents in the Japan Sea. The constant counterclockwise movement of the surface water results from infiltration of a branch of the warm Kuroshsio Current through Tsushima Strait. This Current enters the Japan Sea under the name Tsushima Warm Current and then divides into 3 or 4 branches. Main current swerves to the northeast, flowing along the western shore of Japan. The weaker current flows along the eastern shore of Korea and meeting a cold current from the north, turns southeast, and fuses with the main current at the area off Noto district. Other smaller branches flow between the two. Northward the main current narrows, then much of its water passes through Tsugaru Strait into the Pacific. Most of the remaining current goes through Sôya Strait into the Okhotsk Sea. Only a small part maintains its movement to the north into Tartary Strait along

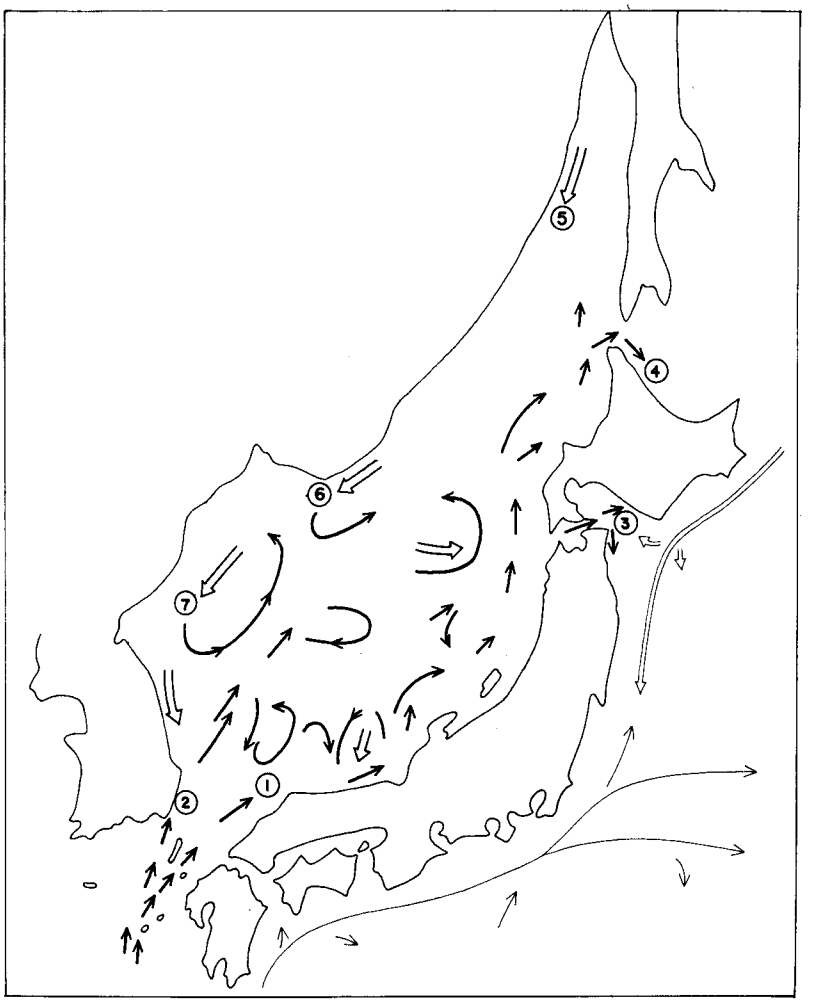


Fig. 1. Scheme of oceanic currents in the Japan Sea.
(1) Tsushima Warm Current.
(2) East Korea Warm Current.
(3) Tsugaru Warm Current.
(4) Sôya Warm Current.
(5) Liman Cold Current.
(6) Maritime Territory Cold Current.
(7) North Korea Cold Current.
(Fisheries Agency, 1958, p. 504)

the western shore of Saghalien. The strength of the Tsushima Warm Current differs with season but the current direction does not. The cold

water of Tartary Strait flows south along the coast of Maritime Territory, carrying with it the fresh water of the many streams that flow off the Sikhote range. This Current, named the Liman Cold Current, passes along the mainland coast and lowers temperatures considerably. It is sometimes called the Maritime Territory Cold Current and North Korea Cold Current as it flows south, meeting the warm current approximately off Kangwon Prov. (about 36°40′–39°10′ N. lat)., and then drops into the depths.

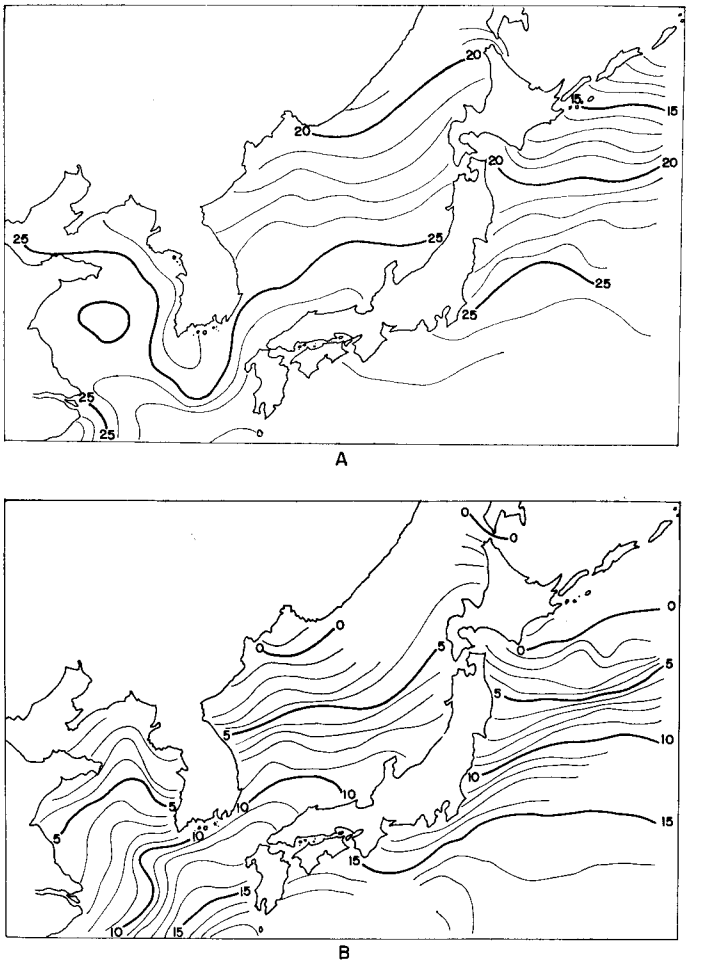


Fig. 2. Distribution of water temperature in the Japan Sea.
A. August.
B. February.
(Bull. Hakodate Marine Observatory, 1958, p. 69, p. 72)

The coast north of Vladivostok is closed by ice during winter and drift ice appears in spring.

The proper water mass characteristic of the depths of the basin is observed in layers below 150–200 m from the surface in the eastern part of the Japan Sea, while it is met with in layers below 20–30 m in the western part.

Fig. 2 shows distribution of surface water temperature. The highest temperature usually occurs in August (Fig. 2A), and the lowest in February (Fig. 2B). In August, 20°C isotherm lies between Vladivostok and north Hokkaido, and isotherm of 25°C between Niigata Pref. and southeast coast of Korea. In this period, the temperature in southern coast of Saghalien is 18–19°C, and near shore of southern Honshu 26–27°C. Around Noto Peninsula, surface temperature rises up to 25–26°C in August. In February, isotherm of 0°C lies between Sôya Strait and off Vladivostok, that of 5°C between southwest Hokkaido and middle Korea, and that of 10°C between Kyoto and south Korea. Around Noto, temperature is 9–10°C in this month. The temperature regime of the Japan Sea changes not only from south to north, but also from west to east, resulted from an influence of Tsushima Current. Along the west coast of Honshu, temperature is higher than that on the Pacific coast influenced by Oyashio Cold Current, if two stations of the same latitudinal position are compared as seen in Fig. 2.

Fig. 3 illustrates seasonal changes of air and surface water temperatures at Maoka, Saghalien; Wakkanai and Esashi, Hokkaido; Tobishima, north Honshu; Wazima, middle Honshu; Hamada, south Honshu; Vladivostok, Maritime Territory of USSR; and Ulrungdo Island and Pusan, Korea. Data on air temperature of Tobishima is substituted with those of Sakata. As for the temperature of Vladivostok, data of mean values of highest and lowest temperatures measured at Ussuriskii Bay were obtained. Months of the year when the highest and lowest temperatures appear, are nearly the same as those shown in Fig. 2. Annual mean value of water temperature at Maoka is 7.0°C, Wakkanai 9.2°C, Esashi 13.1°C, Tobishima 15.4°C, Wazima 16.7°C, Hamada 18.4°C, Pusan 16.3°C, Ulrungdo Island 15.8°C, and Vladivostok 6.9–8.3°C.

Distribution of marine algae in the Japan Sea with reference to phytogeographical positions of Vladivostok and Noto districts

Definition and division of the Japan Sea

On discussing the geographical distribution of marine algae in the Japan

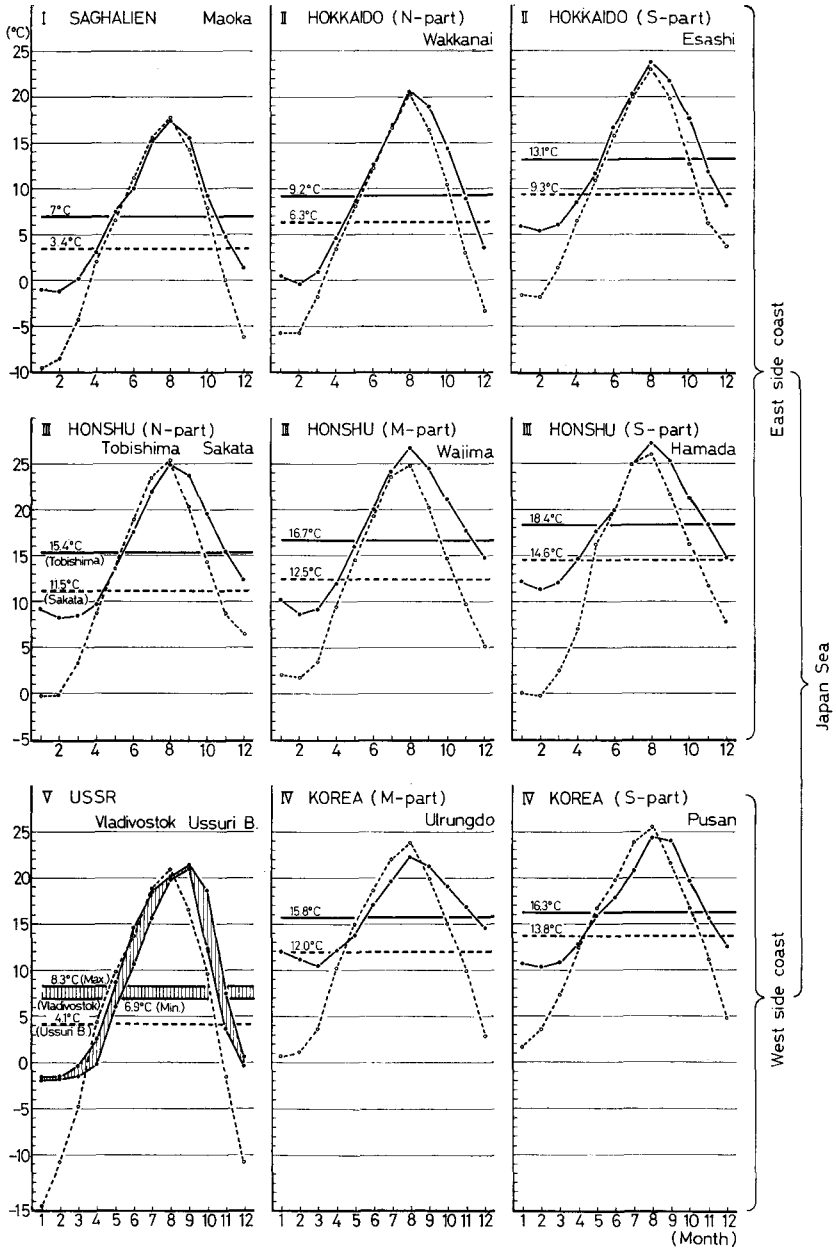


Fig. 3. Surface water temperature and air temperature in the stations along the coast of the Japan Sea, showing annual and monthly average.
——— Surface water temperature. ····· Air temperature.
(TOKIDA, 1954, p. 9, SHINSHI 1963, p. 63, KANG, 1966, p. 5, E. S. ZINOVA, 1928, p. 13)

Sea and characteristic features of Vladivostok and Noto districts from a phytogeographical point of view, a list of marine algae was compiled from previous studies of the present writer as well as from other publications mentioned above, in order to know the names and localities of species reported from this coast.

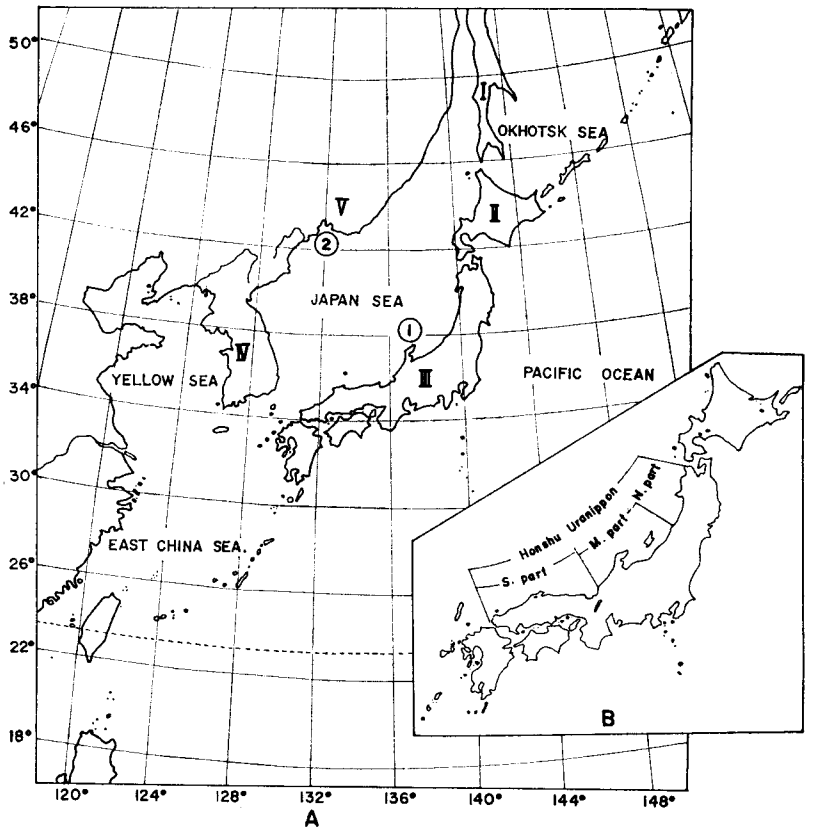


Fig. 4. A. Section of the coast of Japan Sea.
East side: I Saghalien. II Hokkaido.
III Honshu. ① Noto Peninsula.
West side: IV Korea V Maritime Territory.
② Vladivostok.
B. Subdivision of Honshu (SEGAWA, 1956).

The Japan Sea was defined here by setting lines in 4 straits connecting with the neighbouring seas. The lines delimiting the Japan Sea were made by connecting following points, namely;

Tartary Strait: A spot on the coast 50° N latitude in Saghalien, and mouth of Amur River;

Sôya Strait: Cape Nishinotoro in Saghalien, and Cape Noshappu in Hokkaido;
Tsugaru Strait: Cape Shirakami in Hokkaido, and Cape Tappi in Aomori Pref.;
Tsushima Strait: Yoshimi in Yamaguchi Pref., and Pusan in Korea.

The marine algae distributed within these boundaries were treated in the discussions described below.

We can draw an outline of distribution range for each species from the list of algae with their known localities. Coasts of the Japan Sea were divided into following Sections, as shown in Fig. 4, consulting the arguments of OKAMURA (1931, 1932), SEGAWA (1956) and others, in the treatment of geographical distribution.

Eastern shore of the Japan Sea
- I. West coast of Saghalien
- II. West coast of Hokkaido
- III. West coast of Honshu
  - 1) north Honshu, 2) middle Honshu, 3) south Honshu

Western shore of the Japan Sea
- IV. East coast of Korea
- V. Coast of Maritime Territory, USSR.

Although the east coast of Korea was subdivided into two parts, namely north and south, by OKAMURA (l. c.) and KANG (1966), these were treated here undivided because of the difficulties in confirming localities and arrangement of the materials. Vladivostok belongs to Section V, Maritime Territory, and Noto Peninsula to middle Honshu (III–2).

TABLE 3. Surface water temperature of each Section in months of the highest temperature and the lowest (°C)

Section \ Temperature	Month of the highest temp.	Month of the lowest temp.
West coast of Saghalien	≦ 18	− 1– 0
West coast of Hokkaido	20–23	0– 6
West coast of		
north Honshu	23–25	6– 8
middle Honshu	25–26	8–10
south Honshu	26–27	10–13
East coast of Korea	21–25	0–10
Maritime Territory	≦ 21	− 2– 0

Table 3 was constructed from Fig. 2 to represent values of water temperature in the highest and the lowest months for each Section of the coast. From this table, ranges of temperature on the east coast of Korea is known to correspond to those of the west coast of Hokkaido and north or middle Honshu.

Distributional characteristics of each divided Section

Species of marine algae reported from the Japan Sea coast until June, 1967 amounted to 825. Many species have been added since the time of investigation by OKAMURA (l. c.), who treated only 221 species. From a total of 825 species Cyanophyta were excluded, resulting in 748 species.

TABLE 4. Number of species reported from each Section of the Japan Sea*

Section \ Phylum	Chlorophyta	Phaeophyta	Rhodophyta	Total
West coast of Saghalien	24	57	78	159
West coast of Hokkaido	31	59	167	257
West coast of				
north Honshu	29	76	146	251
middle Honshu	35	93	220	348
south Honshu	31	63	101	195
East coast of Korea	50	75	194	319
Maritime Territory	57	85	169	311
Total number	107	208	433	748

* Species of Cyanophyta are excluded.

Table 4 gives the number of species recorded from each Section of the coast. Among these there are many species common to all the Sections of the Japan Sea, or to other neighbouring seas. The species common among all the Sections are as follows: *Ulva pertusa, Enteromorpha linza, Cladophora opaca, Chaetomorpha moniligera, Bryopsis plumosa, Dictyota dichotoma, Leathesia difformis, Sphaerotrichia divaricata, Scytosiphon lomentaria, Colpomenia sinuosa, Petalonia fascia, Chorda filum, Sargassum confusum, S. thunbergii, Bangia fusco-purpurea, Nemalion vermiculare, Grateloupia divaricata, G. turuturu, Gloiopeltis furcata, Schizymenia dubyi, Gracilaria verrucosa, Chondrus pinnulatus* f. *armatus, Lomentaria hakodatensis, Ceramium kondoi, Campylaephora hypnaeoides, Chondria dasyphylla, Laurencia glandulifera,* and *Rhodomela larix.*

These 28 species correspond to 3.8% of the number of species known from the Japan Sea.

In order to illustrate the relationships among these Sections of the coast, and characteristics of the Sections including Vladivostok and Noto Peninsula, proportions of algae restricted to each Section and of algae

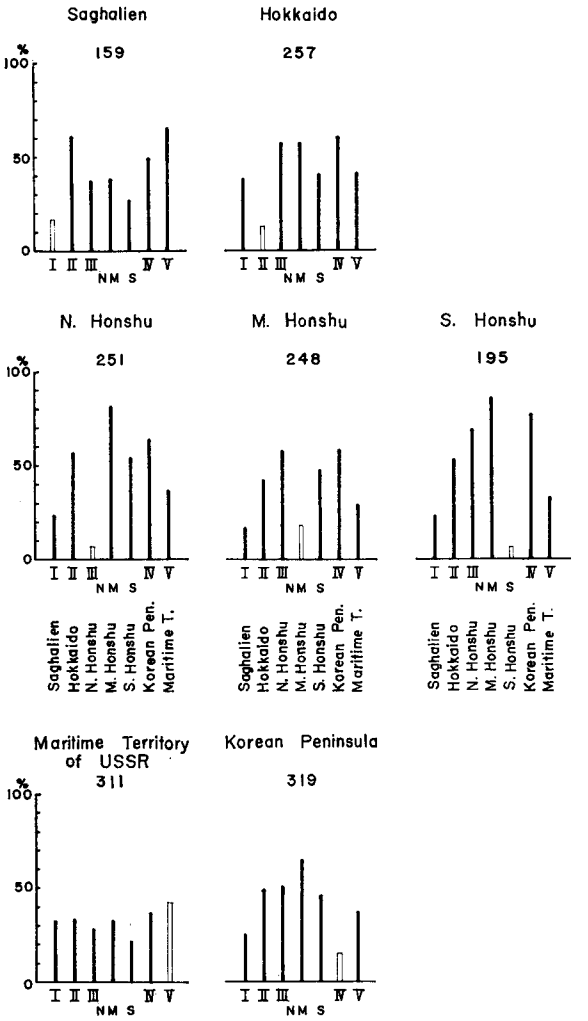


Fig. 5. Proportions of the species peculiar to each Section and of the species common to the other Sections.

Endemic species.

Common species.

common to the other Sections were calculated. This is shown in Fig. 5. In this figure, we can see roughly the similarity between the two Sections concerned, But, it is considered that the relations of Section V, Maritime Territory, to other Sections is not clearly shown, and the comparison is insufficient. This may be caused from the fact that the surveys on each Section are not always of the same value, when we take into account that a larger number of species was recorded from middle Honshu and that the indigenous species were also abundant in the same Section. Cyanophyta were excluded from the consideration, because extensive investigations were made only in a few Sections. This circumstance is also true for other taxa of small size.

Taking these situations into account, 170 species of marine algae were selected according to following qualifications, to indicate clearly the relations among the Sections of the coast.

Qualification for indicator species: 1) macroscopic algae, easy to be collected (microscopic algae excluded); 2) species having clear cut characters, and easy to be identified; 3) exclusive of common species to all the Sections of the Japan Sea. These species may be termed as indicator species.

The numbers of the indicator species belonging in Chlorophyta, Phaeophyta and Rhodophyta in each Section are given in Table 5.

TABLE 5. Number of indicator species of each Section in the Japan Sea

Section \ Phylum	Chlorophyta	Phaeophyta	Rhodophyta	Total
West coast of Saghalien	1	27	27	55
West coast of Hokkaido	3	26	46	75
West coast of				
north Honshu	5	33	38	76
middle Honshu	7	36	53	96
south Honshu	8	33	48	89
East coast of Korea	4	36	56	96
Maritime Territory	1	27	30	58
Total number	11	72	87	170

Fig. 6 illustrates the distributions of all the indicator species in each Section. We can discriminate from this figure temperate or subtropical species extending from south to northward, and subarctic species distributed

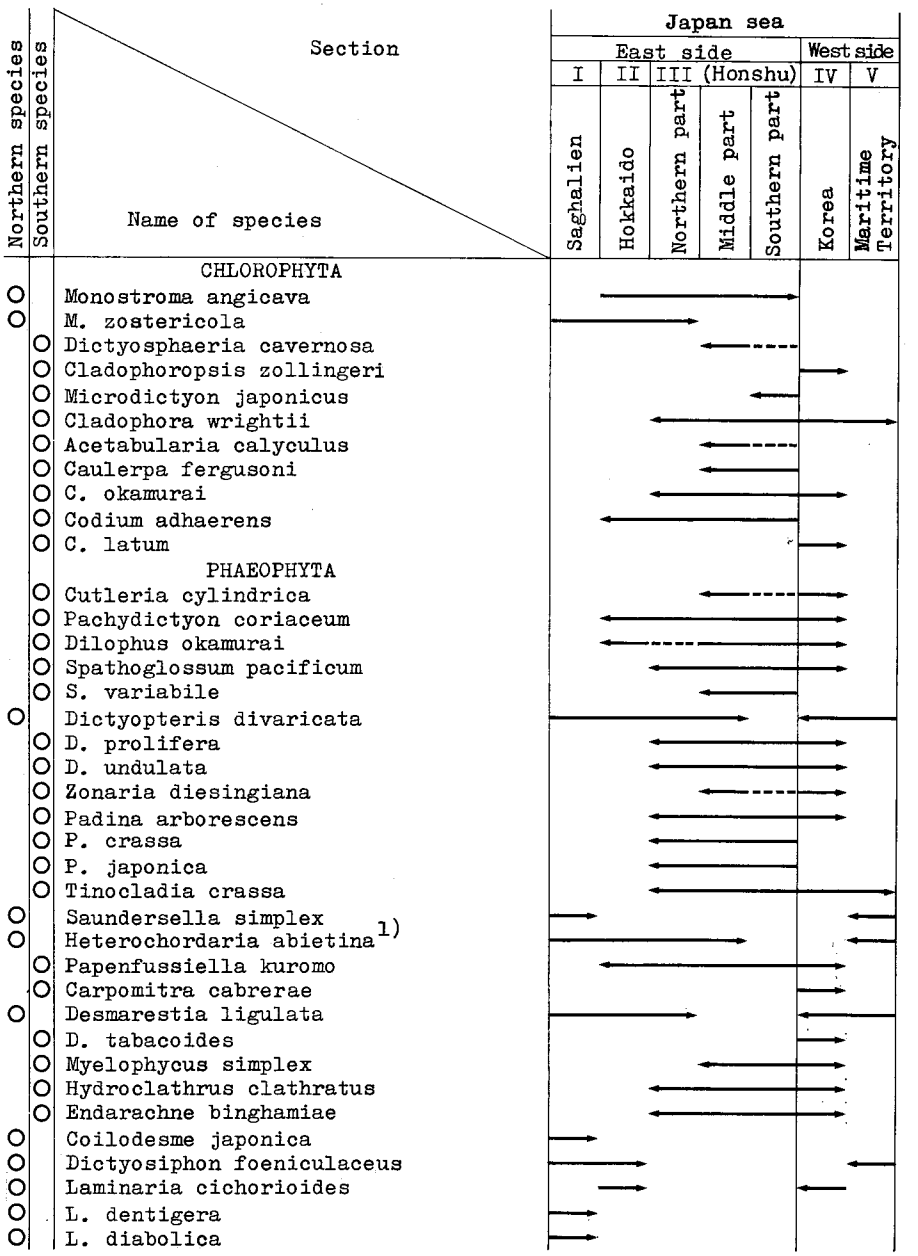


Fig. 6-(1).

Fig. 6 (1)-(4). Distribution of indicator species in the Japan Sea

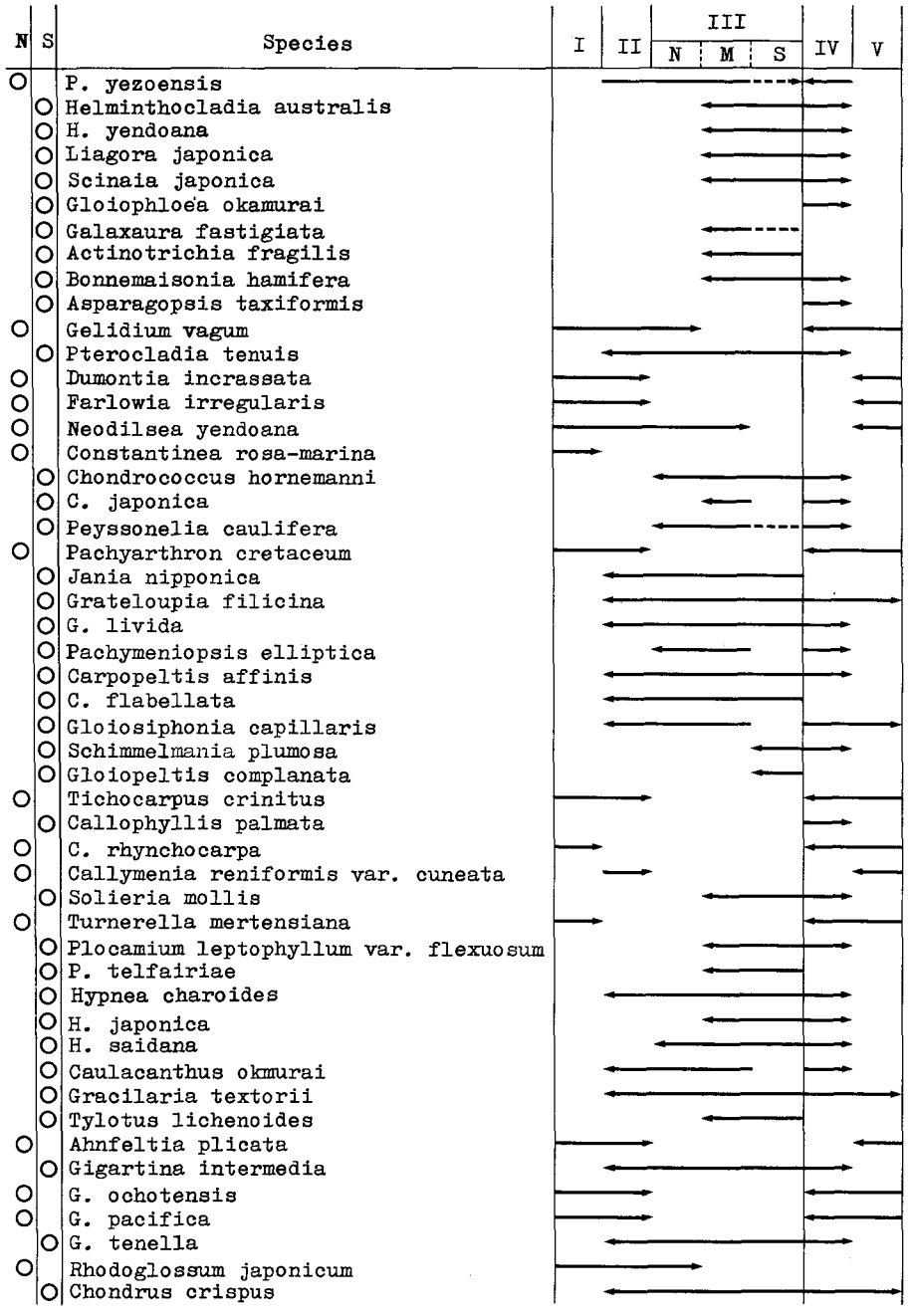
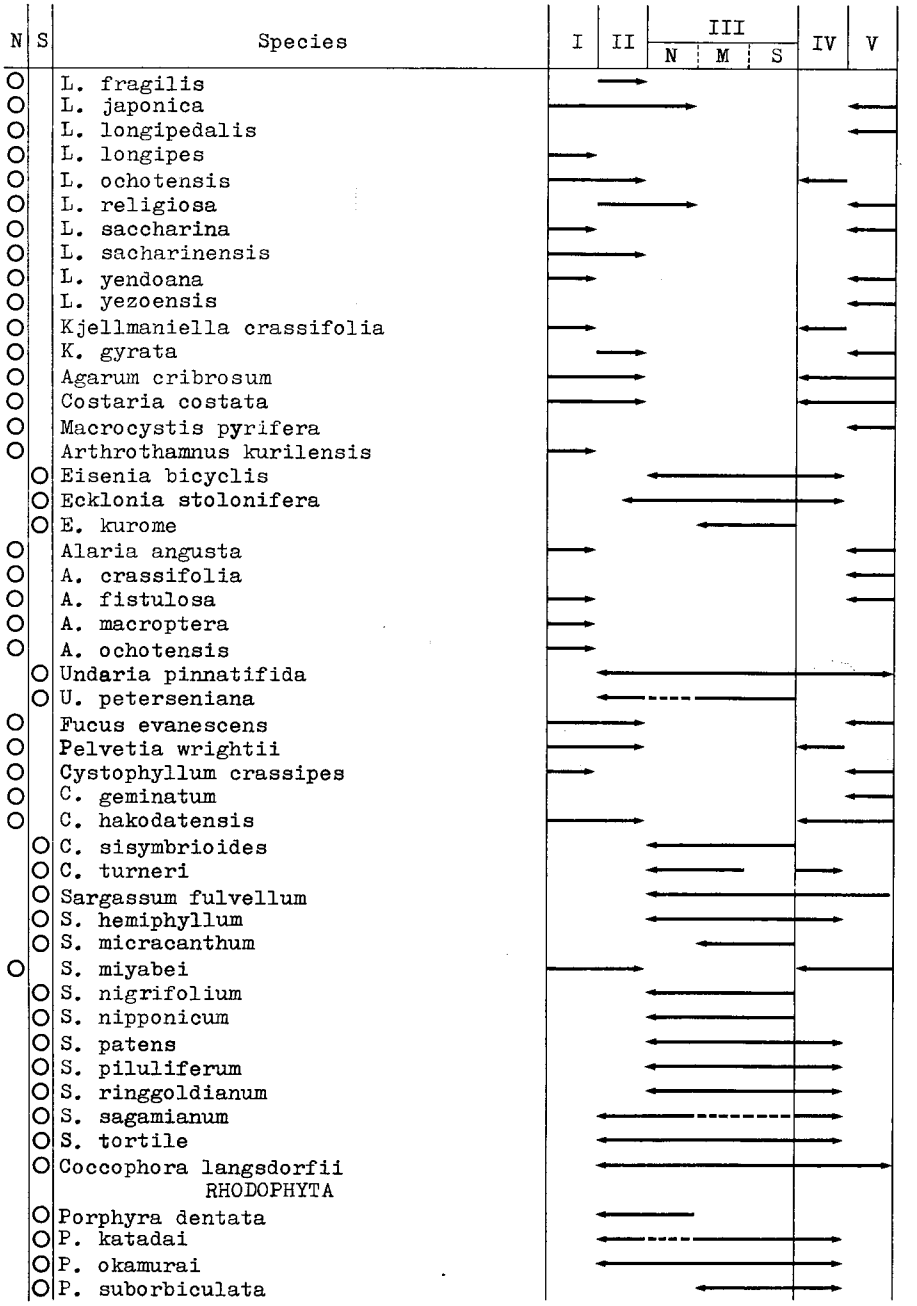

N
S
Species
I
II
III
N
M
S
IV
V
P. yezoensis
Helminthocladia australis
H. yendoana
Liagora japonica
Scinaia japonica
Gloiophloea okamurai
Galaxaura fastigiata
Actinotrichia fragilis
Bonnemaisonia hamifera
Asparagopsis taxiformis
Gelidium vagum
Pterocladia tenuis
Dumontia incrassata
Farlowia irregularis
Neodilsea yendoana
Constantinea rosa-marina
Chondrococcus hornemanni
C. japonica
Peyssonelia caulifera
Pachyarthron cretaceum
Jania nipponica
Grateloupia filicina
G. livida
Pachymeniopsis elliptica
Carpopeltis affinis
C. flabellata
Gloiosiphonia capillaris
Schimmelmania plumosa
Gloiopeltis complanata
Tichocarpus crinitus
Callophyllis palmata
C. rhynchocarpa
Callymenia reniformis var. cuneata
Solieria mollis
Turnerella mertensiana
Plocamium leptophyllum var. flexuosum
P. telfairiae
Hypnea charoides
H. japonica
H. saidana
Caulacanthus okmurai
Gracilaria textorii
Tylotus lichenoides
Ahnfeltia plicata
Gigartina intermedia
G. ochotensis
G. pacifica
G. tenella
Rhodoglossum japonicum
Chondrus crispus

Fig. 6-(2).


N
S
Species
I
II
III
N
M
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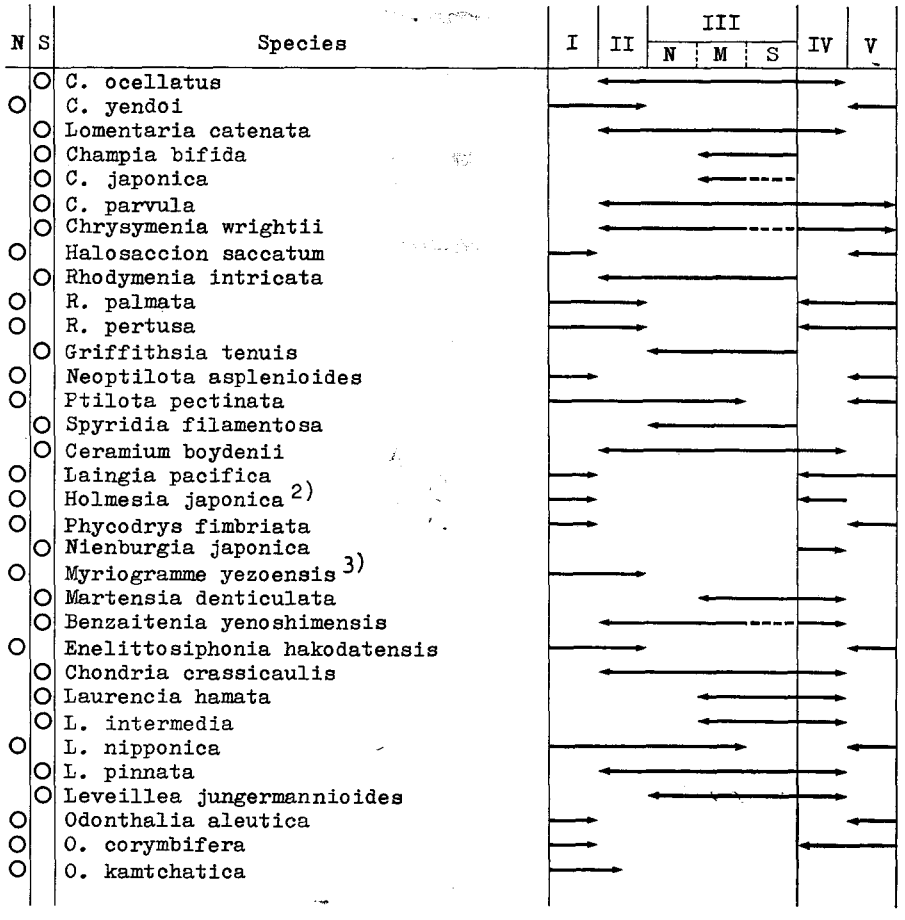
IV
V
L. fragilis
L. japonica
L. longipedalis
L. longipes
L. ochotensis
L. religiosa
L. saccharina
L. sacharinensis
L. yendoana
L. yezoensis
Kjellmaniella crassifolia
K. gyrata
Agarum cribrosum
Costaria costata
Macrocystis pyrifera
Arthrothamnus kurilensis
Eisenia bicyclis
Ecklonia stolonifera
E. kurome
Alaria angusta
A. crassifolia
A. fistulosa
A. macroptera
A. ochotensis
Undaria pinnatifida
U. peterseniana
Fucus evanescens
Pelvetia wrightii
Cystophyllum crassipes
C. geminatum
C. hakodatensis
C. sisymbrioides
C. turneri
Sargassum fulvellum
S. hemiphyllum
S. micracanthum
S. miyabei
S. nigrifolium
S. nipponicum
S. patens
S. piluliferum
S. ringgoldianum
S. sagamianum
S. tortile
Coccophora langsdorfii
RHODOPHYTA
Porphyra dentata
P. katadai
P. okamurai
P. suborbiculata

Fig. 6-(3).



(note)

1) Analipus japonicus (Harvey) Wynne, 1971

2) Neoholmesia japonica (Okamura) Mikami, 1972

3) Nitophyllum yezoensis (Yamada et Tokida) Mikami, 1972

Fig. 6-(4).

from north to south. From this figure, species presumed to grow in the area concerned, considering the distribution in neighboring Sections including western and northern coasts of Kyushu, are represented by dotted lines. These species are treated assuming their presence. Among the indicator species, 103 species (60% of total number) can be called as southern (temperate or subtropical) species and 67 species (40%) as northern (subarctic or arctic) species.

First, proportions of common species in each Section to the other Sections and numbers of endemic species in each Section are calculated using the indicator species presented in Fig. 6. The results are shown in Fig. 7.

Relation between the two Sections under consideration is assumed to be high when the ratio of common species is above 70%, to be significant

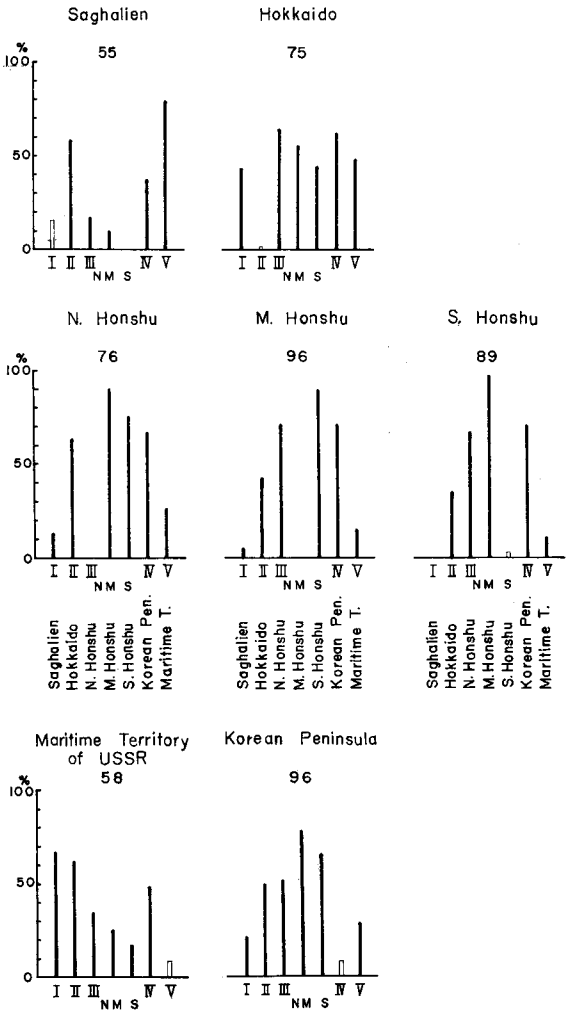


Fig. 7. Proportions of the indicator species peculiar to each Section and of those common to the other Sections.

Endemic species.
Common species.

when the ratio lies between 70 and 50%, to be low when the ratio is 50–30%, and to be less when the ratio below 30%. If this assumption is accepted, the flora of Section I, Saghalien, has a high relation with that of Section V, Maritime Territory, and has a significant relation with that of Section II, Hokkaido. The flora of Hokkaido has a significant relation with those of north and middle Honshu, and with those of Section IV, Korea. The flora of north Honshu has a high relation with those of middle and south Honshu, and has a significant relation with those of Korea and Hokkaido. Middle Honshu, where the Noto Peninsula lies, has a high relation with south and north Honshu and Korea in their floras. The flora of Korea shows a high relation with that of middle Honshu, and shows a significant relation with that of south and north Honshu. Significant relations in the flora are recognized among those of Maritime Territory, where Vladivostok is situated, Saghalien and Hokkaido. Among the floras of the Sections of the coast, it seems that north, middle and south Honshu show a remarkable similarity to each other, than to other Sections. Similarity between the floras of Maritime Territory and Korea is not so remarkable. But, a higher relation may be revealed when the coast of Korea is subdivided into 2 or 3 parts.

Species restricted to each Section are as follows: species restricted to Section I, Saghalien: *Coilodesme japonica, Laminaria dentigera, L. diabolica, L. longipes, Arthrothamnus kurilensis, Alaria macroptera, A. ochotensis, Constantinea rosa-marina.* Species restricted to Section II, Hokkaido: *Laminaria fragilis.* Species restricted to Section III-s, south Honshu: *Microdictyon japonicum, Gloiopeltis complanata.* Species restricted to Section IV, Korea: *Cladophoropsis zollingeri, Codium latum, Carpomitra cabrerae, Desmarestia tabacoides, Gloiophloea okamurai, Asparagopsis taxiformis, Callophyllis palmata, Nienburgia japonica.* Species restricted to Section V, Maritime Territory, USSR: *Laminaria longipedalis, L. yezoensis, Macrocystis pyrifera, Alaria crassifolia, Cystophyllum geminatum.*

Secondly, to consider the characteristic feature of the flora in each Section, proportions of northern and southern species are calculated, spplementing the result obtained from Fig. 7. The proportions for each Section of the coast are shown in Fig. 8. Northern and southern areas are defined here by the occurence of northern or southern species more than 50%, respectively. From this definition, Section I, Saghalien, Section V, Maritime Territory, and Section II, Hokkaido, are included in the northern area, and the southern area includes the coasts of Section III, Honshu, and Section IV, Korea. In the northern area, the proportions of northern species are

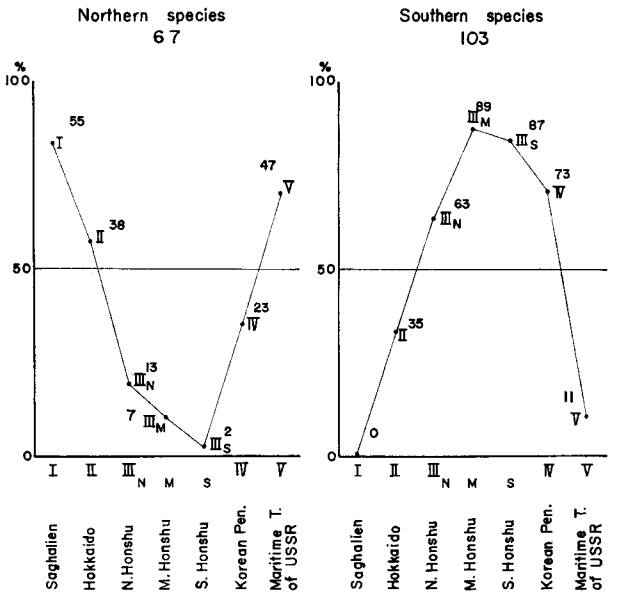


Fig. 8. Proportions of northern and southern indicator species occurring in each Section.

very high in Saghalien and Maritime Territory, but a small proportion of southern species also occur in the two. Although Hokkaido is included in the northern area, it has a tendency to stand near the intermediate area, considering the proportions of both the northern and southern species of algae. OKAMURA (1931, 1932) already stated that Hokkaido was a intermediate area. In the southern area, middle and south Honshu have high proportions of southern species in their floras. North Honshu can also be included in the southern area, but the proportion of southern species is not so high. While Section IV, Korea, has a rather high proportion of the northern species in its flora, it seems appropriate that this relation is fully considered after the coast is subdivided into 2 or 3 parts, as stated already.

Reconsideration on dividing the eastern coast of the Japan Sea

The border line between the northern and southern areas in the eastern shore of the Japan Sea lies in an area between Hokkaido and north Honshu, that is to say, in Tsugaru Strait. In this district, temperatures are 23°C in the highest month, and 6°C in the lowest according to Fig. 3. But, the coast of Hokkaido shows features of intermediate area more clearly than

north Honshu in its flora. The northern limits in distribution of southern species and southern limits of northern species were surveyed in detail on the west coast of Hokkaido by the list of marine algae of the Japan Sea at hand. Only the indicator species were concerned here. Among 35 southern species having their northern limits in Hokkaido, 27 species (77%) occur in the shore south of Otaru, and 12 species (34%) are restricted to south of Okushiri Island, Hiyama Prov. The species restricted in the coast south of Okushiri Island are: *Codium adhaerens*, *Dilophus okamurai*, *Pachydictyon coriaceum*, *Ecklonia stolonifera*, *Undaria peterseniana*, *Sargassum sagamianum*, *S. tortile*, *Porphyra dentata*, *Jania nipponica*, *Hypnea charoides*, *Benzaitenia yenoshimensis*, and *Laurencia pinnata*. On the other hand, 23 northern species have their southern limits of distribution on the west coast of Hokkaido. Among these, 17 species (74%) are distributed on the coast south of Otaru, and 10 species (43%) reached to south of Okushiri Island. The species south of Okushiri are as follows: *Laminaria ochotensis*, *Kjellmaniella gyrata*, *Costaria costata*, *Sargassum miyabei*, *Dumontia incrassata*, *Pachyarthron cretaceum*, *Tichocarpus crinitus*, *Rhodymenia pertusa*, *Myriogramme yezoensis*, *Enelittosiphonia hakodatensis*. Many northern and southern species have their limits of distribution on the west coast of Hokkaido south of Otaru, especially south of Okushiri Island. In this part of the coast, northern and southern species intermixed in nearly the same proportions.

Northern Honshu is examined for the sake of comparison. 27 southern species have their northern limits of distribution in north Honshu. Among them, species with their limits in Aomori Pref. are 12 in number including *Padina arborescens*. Only 5 northern species have their southern limits of distribution in north Honshu. Species with their southern limits in Aomori Pref. are 3, *Desmarestia ligulata*, *Laminaria japonica* and *L. religiosa*.

From considerations of the above, it is better to consider that the boundary between northern and southern areas lies in the southern part of the west coast of Hokkaido, particularly in a area between Okushiri Island and Cape Shirakami, than to draw a line in Tsugaru Strait. Temperature range of this boundary district is 22–23°C in the highest month and 5–6°C in the lowest, as seen from Fig. 3. Bordered by this area, southern species disappear in the area north of Sôya Strait, where its temperature shows a range of 19–20°C in the highest month and 0°C in the lowest, according to Fig. 3, while a few northern species are distributed in middle Honshu where ranges of temperature are between 25–26°C in the highest month and 8–10°C in the lowest. Among them, following 5 species are distributed

so far as middle Honshu: *Dictyopteris divaricata*, *Heterochordaria abietina*, *Neodilsea yendoana*, *Ptilota pectinata*, *Laurencia nipponica*. Only *Monostroma angicava* and *Porphyra yezoensis* extent their distribution ranges to south Honshu.

Along the Japan Sea coast, interrelations among 3 parts of Honshu in the southern area are analysed by the occurrence of southern species. Only a few southern species are restricted in their distribution in south Honshu. These are *Microdictyon japonicum*, *Schimmelmania plumosa* and *Gloiopeltis complanata*. Middle Honshu has 28 subtropical or temperate species having their northern limits in distribution, for example: *Dictyosphaeria cavernosa*, *Acetabularia calyculus*, *Caulerpa fergusoni*, *Zonaria diesingiana*, *Galaxaura fastigiata*, *Actinotrichia fragilis*, *Hypnea japonica*, *Martensia denticulata*. Among these, 9 species including *Acetabularia calyculus*, *Dictyosphaeria cavernosa* and *Caulerpa fergusoni* showed their northern limits of distributon in Noto district. Southern species distributed to northern Honshu, amount to 27 species including *Cladophora wrightii*, *Caulerpa okamurai*, *Dictyopteris prolifera*, *Padina crassa*, *Hydroclathrus clathratus*, *Eisenia bicyclis*, *Sargassum fulvellum*, *Chondrococcus hornemanni*, *Peyssonnelia caulifera*, *Spyridia filamentosa* and *Leveillea jungermannioides*.

There seem to exist alternative ideas in subdividing the coast of Honshu, deduced from the above discussion and examination of Fig. 8. The one idea is that the coast of Honshu is divided into 3 parts, namely, south, middle and north, according to the current treatment which took into

TABLE 6. A trial of the division of the eastern side of the Japan Sea from the phytogeographical point of view

Zone \ Temperature	Water temperature		
	the highest month	the lowest month	annual average in coastal station
Arctic and subarctic zones West coast of South Saghalien	below 20°C	below 0°C	7°C (Maoka)
Southern part of subarctic zone West coast of Hokkaido	20–22°C	0–5°C	9.2°C (Wakkanai)
Intermediate region between subarctic and temperate zones Southwest coast of Hokkaido	22–23°C	5–6°C	13.1°C (Esashi)
Northern part of temperate zone Northwest coast of Honshu	23–25°C	6–9°C	15.4°C (Tobishima)
Southern part of temperate zone Southwest coast of Honshu	above 25°C	above 9°C	18.4°C (Hamada)

account the relations between south Honshu and Tsushima Strait or north Kyushu. Another is that the coast of Honshu is subdivided into 2 parts by a boundary near north of Noto district. In all events, it is clear that the marine flora of Noto Peninsula has a nearly central transitional characteristic from a phytogeographical point of view.

In conclusion, we can introduce following division of eastern side of the Japan Sea (Table 6), although this method of division may require further confirmations.

Around the Noto Peninsula, which lies in bordering area between north and south temperate zone, the water temperature range is 25–26°C in the highest month and above 9°C in the lowest. Mean annual water temperature is 16.7°C at a station of observation (Wazima) as seen in Figs. 2 and 3.

On the division of the western coast of the Japan Sea

On the western coast of the Japan Sea, a line separating northern and southern area is a border line between Korea and Maritime Territory, USSR, from Fig. 8. Several southern species, however, extend their distribution ranges to Maritime Territory, and certain northern species are distributed to the coast of Korea. Among the indicator species, following southern species have their northern limits of distribution in Maritime Territory: *Cladophora wrightii, Tinocladia crassa, Undaria pinnatifida, Sargassum fulvellum, Coccophora langsdorfii, Grateloupia filicina, Gloiosiphonia capillaris, Gracilaria textorii, Chondrus crispus, Champia parvula, Chrysymenia wrightii.* On the other hand, northern species extended to the coast of Korea are as follows: *Dictyopteris divaricata, Desmarestia ligulata, Laminaria cichorioides, L. ochotensis, Kjellmaniella crassifolia, Agarum cribrosum, Costaria costata, Pelvetia wrightii, Cystophyllum hakodatensis, Sargassum miyabei, Porphyra yezoensis, Gelidium vagum, Pachyarthron cretaceum, Tichocarpus crinitus, Callophyllis rhynchocarpa, Turnerella mertensiana, Gigartina ochotensis, G. pacifica, Rhodymenia palmata, R. pertusa, Holmesia japonica,* and *Odonthalia corymbifera.*

Similar discussions to those in the eastern coast would be made to subdivide the coasts of both Maritime Territory and Korea into 2 or 3 smaller area as done by OKAMURA (l. c.) and KANG (l. c.), judging from the fact that there are a relatively large number of southern species distributed in Maritime Territory, and of northern species extended to the coast of Korea. But a full treatment is at present hampered by the state of our knowledge that the distribution in each species could not be localized precisely. But

lines delimiting the subdivisions might be drawn by ranges of temperature similar to those discussed on the eastern coast. At Vladivostok, the temperature range is 20°C in the highest month and −1°C in the lowest, with the annual mean value of 6.9–8.3°C. This range is similar to that in Soya Strait. But the occurence of southern species such as *Undaria pinnatifida*, *Coccophora langsdorfii*, *Gloiosiphonia capillaris*, *Champia parvula*, and *Chrysymenia wrightii* might mean a closer similarity to north Hokkaido than Saghalien.

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Summary

1. In this paper, the distribution of marine algae on the Japan Sea coast was discussed with reference to the distributional positions of Vladivostok and Noto districts.

2. The Japan Sea coast was divided into five Sections and three Subsections in consonance with previous studies, and 170 species were selected as indicator species.
3. First, according to the investigation of the proportions of the indicator species common between one Section and each of the other Sections, floristic relationships among the Sections were shown.
4. Secondly, among the indicator species, 103 southern and 67 northern species were discriminated acoording to their ranges of distribution. By the respective proportions of the southern and northern species in each Section, phytogeographical features of each Section were made clear and the Japan Sea coast was divided into two areas; northern area (Sections I Saghalien, II Hokkaido and V Maritime Territory of USSR) and southern area (Sections III Honshu and IV Korea).
5. Detailed considerations on boundary between northern and southern areas in the eastern side of the Japan Sea showed that the intermediate zone lies on the southwestern coast of Hokkaido.
6. An alternative idea to the current subdivision of Honshu into 3 parts is that the Honshu coast may be subdivided into two northern and southern parts where the region north of Noto Peninsula is the dividing line.
7. Details of the distribution on the coasts of Korea and Maritime Territory of USSR of the western side of the Japan Sea were not able to be discussed sufficiently, because of the inability to localize collections and thus distribution in each species. But the ranges of temperature mentioned in the division or subdivision of the eastern coast may give a suggestion for the future investigation of the coast.
8. In the course of the above investigations, it is concluded from the phytogeographical point of view that Noto Peninsula is a nearly central transitional district in the temperate zone of Honshu, and that Vladivostok district has a closer similarity to the northern part of west coast of Hokkaido than to South Saghalien.

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