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ASSOCIATIONS OF PLANKTON DIATOMS AROUND
JAPAN AS INVESTIGATED BY UNDERWAY
SAMPLINGS ABOARD THE "OSHORO MARU"
IN OCTOBER AND DECEMBER 1952 *

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I. Introduction

The training ship "Oshoro Maru" of the Faculty of Fisheries, Hokkaido University, made a round-Japan cruise from October 14 to December 15, 1952. The purpose of this cruise was not only for the regular training of cadets in navigation and seamanship, but also for a preliminary trial of undersea observations at several localities along the coasts of Japan Islands by means of the "Kuroshio", Undersea Observation Chamber (Inoue *et al.*, 1953) under supervision of Prof. N. Inoue, Faculty of Fisheries, Hokkaido University, and Dr. T. Sasaki, Scientific Research Institute, Tokyo. On this occasion Prof. Motoda who was on board the ship made collections of the surface plankton by underway samplings through the whole course of the cruise off the coasts of Honshu and Kyushu. These samples of plankton were put at the disposal of the present author. The plankton diatoms are dealt with in the present paper.

In Japanese waters in recent years a group of planktologists in Marine Observatories, Ministry of Transportation, has contributed to understanding the nature of water masses by observing the distribution of plankton diatoms.

With similar intention the present investigations were originally undertaken to observe how the diatom associations vary with the localities around the coasts of Japan within the comparatively short period of one cruise. There are such ocean currents around Japan that were traversed in the present cruise as the Tsushima Current off Japan Sea coasts, the Kuroshio (Japan Current) and Oyashio (Kurile Current) off the Pacific coasts. The particular interest may be aroused by the manner in which varying hydrographic conditions resulting from geographical and climatic effects during continuous flow of such currents, either southwards, or northwards, are reflected in the change of diatom associations. However, the track of the ship in the present cruise did not always follow a particular ocean current; the track was located very close to the coast, passing through the purely coastal waters, in certain areas, while in other areas it was shifted comparatively to the offing, touching with the prevailing ocean current. Accordingly, the findings herewith reported render possible some considerations such as above mentioned at some places, but in most descriptions are concerned with merely the findings in respect to

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characteristics in diatom associations in various localities at that time wheresoever inshore or offshore waters.

Before going further, the author wishes to express his sincere gratitude to Prof. S. Motoda under whose guidance he initiated his scientific research work. Cordial thanks are also due to from the author to Dr. T. Kawamura and Mr. M. Anraku for their many valuable advices given throughout the laboratory work. Kind help extended by Captain T. Fujii and his crew and cadets, and Prof. N. Inoue and Dr. T. Sasaki and their scientific staff aboard the ship during that cruise is gratefully appreciated.

II. Method, Location and Date of Samplings

The Handy Underway Plankton Catcher, model I, (Motoda, 1954) was employed in sampling the plankton materials. To sample the microplankton, composed mainly of phytoplankton, while underway, a narrow conical net of fine mesh bolting silk, XX 13, *i. e.*, 129 meshes per linear inch, having approximately 0.11 mm mesh opening, is inserted into the catcher. As the catcher, model I, is very narrow, 5 cm in diameter of cylindrical case, and as it has a tapering head piece, it is easy to handle at high speed tow. The instrument was towed at the end of twenty-five meters of cotton flag line at a speed of about 9 knots for 30 minutes or less; duration of tow depended upon the circumstances.

Tows were made by cadets or sailors at intervals of four hours while the ship was sailing. The net inside was often clogged with sticky materials; on such an occasion it was washed to clean it out. The instrument was not equipped with any sinking vane, but it was supported by a heavy head piece to run through the water at about a half meter or so below the sea surface. There was no equipment such as current meter to measure the volume of water filtered by the net inside or to measure the exact distance of tow, so that the samples obtained are not available for accurately quantitative studies, but may be used for rough estimation of relative abundance of population. Of all of the samples the number of cells, often composing colonies, were counted for each species so far as identified.

Approximate location of the stations where collections were made is illustrated in Fig. 1, and more exact data on the position of the stations, date and hour of collections and temperature of the surface water at that time are given in Table 1. Total sum of the sample vials amounted to sixty-six, but that from St. 57 was lost and those from St. 35 and St. 36 did not contain any organism, but only water. These are omitted from the data.

III. Results of Observations

For the sake of convenience in arrangement descriptions will be made following the track of the ship in chronological order from departure, by grouping some of the stations on

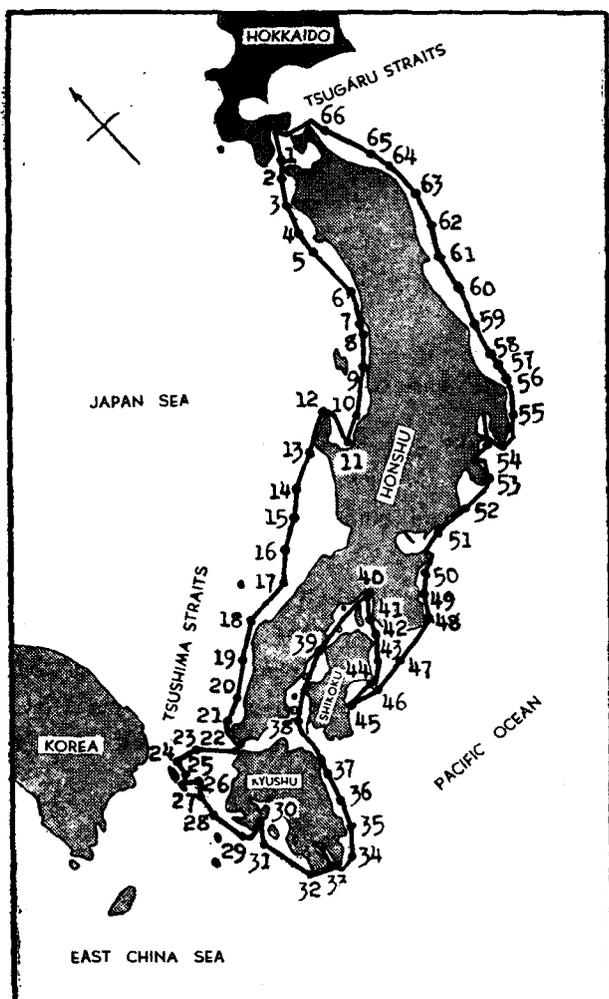


Fig. 1. Sketch map of Japan Islands showing track of the cruise and stations of sampling

known in this region as one of the representatives of tropical diatoms which appear with drift of northwards Tsushima Current from southern seas in autumn (Asamushi Marine Biological Station, 1946-49; Kokubo, 1952; Hakodate Marine Observatory, 1954). Next comes *Chaetoceros didymus* occupying about 20 % of total cells. It is a warm temperate species. The prevalence of above species indicates the inflow of a tributary current of the Tsushima Current into Tsugaru Straits in this season.

(2) St. 3-13 (Japan Sea coast of northern Honshu)

The course of the ship is located adjacent to the coast. Total cell number is counted as between 4,800 and 190,000 and 72,000 in average. Species number is eighty-four.

the basis of neighbouring geographical situation and of apparently common associations of diatom population. Full data are given in Table 3 and summarized results in Table 2. Number of cells recorded in the text and table are only concerned with the number obtained by a tow of definite duration; all data are converted for thirty minutes' tow. It is natural that these numbers are far less than the actual number of cells which must be present in the volume of water that has been passed through the mouth opening of the instrument for such duration of tow. The filtration coefficient in such underway samplings will be much less than found in case of the use of other methods.

(1) St. 1 and 2 (Tsugaru Straits)

Cell number of total diatoms is from 3,900 (St. 1) to 25,200 (St. 2), averaging 14,550. Total species number is thirty-five. The most prevalent form is *Chaetoceros coarctatus*. This species has been

The leading species are *Chaetoceros coarctatus*, *Ch. decipiens*, *Ch. lorenzianus*, *Ch. didymus*, *Ch. distans*, *Climacodium biconcavum*, *C. Frauenfeldianum* and *Thalassionema nitzschioides*, though some of them are absent at some stations. *Chaetoceros coarctatus* has never occupied more than 20 % of total cells. *Hyalochaete* occupied about 50 % of total diatoms, and warm current species are found more or less commonly in the localities from Noto Peninsula to Niigata, agreeing with previous reports (Aikawa, 1936; Kawarada, 1953; Shimomura, 1954a). There are large concentrations of diatom population at St. 9 (188,400 cells) and St. 13 (179,400 cells), in which *Hyalochaete* and *Thalassionema nitzschioides* are dominant.

(3) St. 14 and 15 (Off Wakasa Bay)

These stations are located in the offing. Total cell number ranged from 7,800 (St. 14) to 32,800 (St. 15), with 20,300 in average. Number of species is twenty-one. Generally diatom population is poor both in total cell number and in species number. *Chaetoceros coarctatus* is the leading species, occupying 76 % of total diatom cells. It is followed by *Climacodium* and *Rhizosolenia*. The prevalence of tropical and subtropical oceanic species as well as the poverty in total cells indicates that the ship has passed through the water of the Tsushima Current. Shimomura (1954b) reported that the Tsushima Current off Wakasa Bay is characterized by decrease in number of plankton, particularly of phytoplankton; the more one goes to the northeast in the path of this current, the less number of plankton he finds.

(4) St. 16-21 (Japan Sea coast of southern Honshu)

Total cell number lies between 17,000 and 427,500, with 176,700 in average. Species number is sixty-seven. *Hyalochaete* occupies more than 50 % of total diatoms. *Chaetoceros lorenzianus* and *Ch. didymus* are dominant through all stations; *Ch. compressus* is dominant at St. 17-19, and *Ch. messanensis*, *Ch. distans*, and *Ch. radicans* are at St. 19-21. Aikawa (1936) reported that *Hyalochaete* occupies more than 50 % of total phytoplankton on southern Japan Sea coast of Honshu being followed by *Nitzschia seriata* and *Bacteriastrum* in autumn. There are high concentrations of diatom population at St. 16 (362,000 cells) and St. 19 (408,000 cells), in which *Hyalochaete* and *Thalassionema nitzschioides* are dominant. St. 16 is located near the coast of the Oki Islands where the abundance of diatoms has been induced possibly by the upwelling of underwater near the islands, though physical proof is not obtained. According to Aikawa (1934), the vicinity of the Oki Islands is a high productive area, and also to Shimomura (1954b), the phytoplankton is very abundant from the north of the Oki Islands to the offing of Wakasa Bay. Shimomura suggested that the abundance of phytoplankton off Wakasa Bay in summer is due to the upwelling water in that region.

Table 1. Record of collections

No. of station	Date	Hour	Position		Locality	Temperature of surface water (°C)	Remarks
			Lat.	Long.			
St. 1	October 14	17:00-17:30	41-27-00 N.	140-25-09 E.	Tsugaru Straits	18.5	
" 2	" "	20:15-20:45	41-08-00 N.	140-10-03 E.	Off Cape Gogensaki	21.5	
" 3	" "	00:00-00:30	40-38-00 N.	139-48-00 E.	Off Henashi	19.0	
" 4	" "	04:00-04:30	40-15-00 N.	139-38-00 E.	Off Noshiro	21.5	
" 5	" "	08:00-08:30	39-51-30 N.	139-26-00 E.	Off Ojika Peninsula	20.5	
" 6	" "	11:50-12:20	38-47-30 N.	139-37-00 E.	Off Sakata	21.0	
" 7	" "	16:00-16:30	38-12-30 N.	139-19-00 E.	Off Senami	22.0	
" 8	" "	19:45-20:15	38-12-30 N.	139-12-30 E.	"	22.2	
" 9	" "	23:45-00:15	37-50-00 N.	138-44-00 E.	Off Niigata	27.5	
" 10	" "	07:45-08:00	37-09-05 N.	137-56-00 E.	Off Naoetsu	23.0	
" 11	" "	12:15- ?	36-54-08 N.	137-19-42 E.	Toyama Bay	22.5	
" 12	" "	?	37-36-00 N.	137-18-00 E.	Off Noto Peninsula	—	
" 13	" "	19:45-20:15	37-19-00 N.	136-28-05 E.	"	22.0	
" 14	" "	23:45-00:15	37-00-00 N.	135-30-00 E.	Off Tsuruga	19.0	
" 15	" "	03:45-04:15	36-39-07 N.	135-01-05 E.	"	20.0	
" 16	" "	07:45-08:00	36-18-01 N.	134-18-09 E.	Off Tottori	20.4	
" 17	" "	11:45-12:15	35-51-05 N.	133-51-05 E.	"	22.4	
" 18	" "	15:45-16:15	35-35-02 N.	132-55-08 E.	Off Mastue	20.3	
" 19	" "	19:45-20:15	35-13-05 N.	132-10-00 E.	Off Hamada	22.1	
" 20	" "	23:45-00:15	34-44-00 N.	131-22-00 E.	Off Senzaki	20.4	
" 21	" "	03:45-04:15	34-28-00 N.	130-52-02 E.	"	22.2	
" 22	" "	23:45-00:15	34-08-04 N.	130-38-00 E.	Off Kokura	22.0	
" 23	" "	03:45-04:15	34-30-00 N.	130-02-00 E.	Tsushima Straits	19.8	
" 24	" "	07:45-08:15	34-44-00 N.	129-31-07 E.	Northeast coast of Tsushima	22.2	
" 25	" "	16:15-16:45	34-18-05 N.	129-26-05 E.	East coast of Tsushima	21.8	
" 26	" "	15:30-16:00	34-04-14 N.	129-33-00 E.	Tsushima Straits	—	
" 27	" "	19:45-20:15	33-53-05 N.	129-31-00 E.	"	21.8	
" 28	" "	03:45-04:15	33-20-03 N.	129-17-08 E.	Off Hirato	23.0	
" 29	" "	15:45-16:15	32-48-06 N.	129-35-02 E.	Off Nagasaki	21.0	
" 30	November 6	10:30-11:00	32-42-00 N.	130-01-00 E.	Tachibana Bay	20.4	
" 31	" "	20:15-20:30	32-29-02 N.	129-42-02 E.	Off Cape-Nomo	17.0	
" 32	" "	23:45-00:15	31-15-08 N.	130-07-01 E.	Off Makurasaki	20.4	
" 33	" "	11:45-12:15	31-10-01 N.	130-42-01 E.	Kagoshima Bay	22.5	
" 34	" "	15:45-16:15	31-06-00 N.	130-58-00 E.	Ohsumi Straits	21.9	
" 35	" "	19:45-20:15	31-27-00 N.	131-26-08 E.	Off Aburatsu	23.0	Empty
" 36	" "	23:45-00:15	31-59-02 N.	131-41-08 E.	Off Miyazaki	23.0	Empty
" 37	" "	03:45-04:15	32-29-01 N.	131-52-06 E.	Off Nobeoka	23.0	
" 38	" "	11:45-12:15	33-33-02 N.	132-12-00 E.	Iyo-Nada	21.0	
" 39	" "	07:45-08:15	34-20-06 N.	133-43-00 E.	Bingo-Nada	19.8	
" 40	" "	16:30-17:70	34-37-00 N.	135-10-04 E.	Izumi-Nada	19.6	
" 41	" "	11:45-12:15	34-13-01 N.	134-55-09 E.	Off Wakayama	19.5	
" 42	" "	19:45-20:15	34-02-01 N.	134-48-08 E.	Kii Channel	19.4	
" 43	" "	23:45-00:15	33-25-05 N.	134-28-00 E.	East of Cape Muroto	21.4	
" 44	" "	03:45-04:15	33-13-06 N.	133-57-08 E.	Off Cape Muroto	22.5	
" 45	" "	16:00-16:30	33-16-06 N.	133-19-00 E.	Tosa Bay	22.4	
" 46	" "	19:45-20:00	33-12-04 N.	134-00-00 E.	West of Cape Muroto	22.5	
" 47	" "	23:45-00:15	33-14-02 N.	134-38-00 E.	Off Kii Channel	21.4	
" 48	" "	07:45-08:15	33-33-02 N.	135-58-06 E.	Off Cape Shionomisaki	22.1	
" 49	" "	11:45-12:15	33-17-00 E.	136-17-00 E.	Off Owase	19.0	
" 50	December ?	07:45-08:15	34-05-05 N.	136-26-01 E.	"	21.0	
" 51	" "	3 19:45-20:15	34-29-00 N.	137-33-02 E.	Enshu-Nada	19.8	
" 52	" "	4 23:45-00:15	34-33-01 N.	138-24-00 E.	Off Omaezaki	19.0	
" 53	" "	03:45-08:15	34-38-02 N.	139-05-05 E.	Off Shimoda	16.6	
" 54	" "	8 07:45-08:15	35-06-08 N.	139-36-08 E.	Sagami Bay	19.1	
" 55	" "	13 15:45-16:15	35-13-06 N.	140-32-03 E.	Off Katsuura	20.0	
" 56	" "	" 19:45-20:15	35-48-05 N.	140-58-05 E.	Off Cape Inubosaki	17.5	
" 57	" "	" "	" "	" "	"	—	No sampling
" 58	" "	" 23:45-00:15	36-26-00 N.	141-15-00 E.	Off Mito	17.1	
" 59	" "	14 03:45-04:15	37-03-07 N.	141-12-05 E.	Off Cape Shioyasaki	15.5	
" 60	" "	" 07:45-08:15	37-40-05 N.	141-23-05 E.	Off Haranomachi	14.2	
" 61	" "	" 11:45-12:15	38-16-01 N.	141-39-03 E.	Off Kinkazan	12.5	
" 62	" "	" 15:45-16:15	38-52-00 N.	141-52-06 E.	Off Kesenuma	11.8	
" 63	" "	" 19:45-20:15	39-27-05 N.	142- E.	Off Kamaishi	12.0	
" 64	" "	15 23:45-00:15	40-20-00 N.	142-08-02 E.	Off Kuji	12.3	
" 65	" "	" 03:45-04:15	40-39-02 N.	142-06-00 E.	Off Hachinohe	12.0	
" 66	" "	" 07:45-08:15	41-19-02 N.	141-31-07 E.	Off Cape Shiryasaki	14.0	

(5) St. 22 (Genkai-Nada)

Total cell number is very large, amounting to 1,217,400, and species number is thirty-nine. *Chaetoceros radicans* is the most prevalent species, occupying 34 % of total cells. *Ch. lorenzianus*, *Ch. compressus*, *Ch. messanensis*, *Ch. curvisetus* and *Lauderia borealis* are also important constituents of the take.

(6) St. 23 27 (Tsushima Straits)

Total cell number is between 162,000 and 273,000 per haul in the straits, while it is between 450,000 and 1,445,000 on the coast of Tsushima Island, averaging 513,000. Species number is sixty eight. *Chaetoceros decipiens*, *Ch. lorenzianus*, *Ch. didymus*, *Ch. compressus*, *Ch. curvisetus*, *Ch. radicans* and *Ch. messanensis* are dominant, being followed by *Ch. atlanticus* v. *neapolitana*, *Ch. rostratus* and *Lauderia borealis*. *Eucampia zoodiacus* is reported to be prevalent in the straits in the fourth quarter of the year (Kokubo, 1931-40, 1937), but in the present observations this species is not found in the straits, but in the Hirato Channel.

(7) St. 28 and 29 (Hirato Channel)

Total cell number is 127,200 at St. 29 and 457,800 at St. 28, averaging 292,500. Species number is fifty-four. The leading species is *Eucampia zoodiacus*, being followed by *Chaetoceros decipiens* and *Ch. lorenzianus*.

(8) St. 30 and 31 (Amakusa-Nada)

Diatoms are abundant both in total cell number and species number. Total cell number is 792,000 at St. 30 and 5,064,000 at St. 31. The latter value is the largest one among the data obtained from all stations in the present observations. Average of cell number is 2,928,000. Species number is forty-one. *Skeletonema costatum* (21 %) and *Asterionella japonica* (19 %) are dominant at St. 31, while *Chaetoceros pseudocruvisetus* (34 %) and *Melosira nummuloides* (19 %) are dominant at St. 30. Next to the above four species, *Ch. curvisetus* and *Eucampia zoodiacus* are important constituents. The complicated coastal currents which might be associated with the topographic contours are possibly responsible for the high production of diatoms (cf. Aikawa, 1934).

(9) St. 32 (Southwest coast of Kyushu)

Total cell number is 2,742,000, and species number is fifty-seven. The most prevalent species is *Chaetoceros messanensis*, being followed by *Ch. compressus*, *Ch. pseudocruvisetus*, *Ch. didymus*, *Ch. radicans*, *Lauderia borealis*, *Bacteriastrum comosum* and *Rhizosolenia Stolterfothii*.

(10) St. 33 (Kagoshima Bay)

The station is located at the entrance of Kagoshima Bay. Total cell number is as large as 3,367,200, and species number is fifty-two. The components of diatoms are fairly different from those at other localities of west coast of Kyushu. *Thalassionema nitzschioides* and *Chaetoceros pseudocruisetus* are dominant, being followed by *Ch. compressus*, *Nitzschia seriata*, *Biddulphia sinensis*, *Hemiaulus sinensis*, *H. indica*, and *Climacodium*. *Planktoniella sol* and *Gossleriella tropica* are also found in a certain abundance. The occurrence of tropical or warm-water species is notable; the influence of the Kuroshio Current is apparently indicated in diatom associations at the entrance of this bay.

(11) St. 34 and 37 (Hyuga-Nada)

Diatoms are rather poor both in total cell number and in species number. Total cell number is 18,300 at St. 34 and only 2,940 at St. 37, averaging two stations 10,620 cells. Species number is twenty-nine. The leading species is *Thalassionema nitzschioides*, occupying 50 % at St. 34 and 38 % at St. 37. *Climacodium biconcavum* (18.3%) and *Melosira nummuloides* (18 %) are also important. This region is supposed to be under the influence of the Kuroshio Current, as is reflected in high temperature and in the prevalence of tropical diatoms as well.

(12) St. 38 (Iyo-Nada)

This station is located in the Inland Sea (Seto-Naikai). The diatom associations are distinct from those of Hyuga-Nada. Total cell number is 34,110 and species number is more than nine. *Coscinodiscus* is the most prevalent group, occupying 86 % of total cells, while *Eucampia zodiacus* and *Hemidiscus cuneiformis* follow. Kokubo (1931-40) and Maekawa et al. (1953) reported the predominance of *Coscinodiscus* in the more western part in the Inland Sea in winter.

(13) St. 39 (Bingo-Nada)

Total cell number is 262,800 and species number is more than nineteen. *Coscinodiscus* is the most prevalent group, occupying 52 % of the total cells. In addition, the following diatoms are important constituents; *Hemidiscus cuneiformis*, *Stephanopyxis palm-eriana*, *Skeletonema costatum*, *Lauderia borealis*, *Rhizosolenia Bergonii*, *Bacteriastrum hyalinum*, *B. mediterraneum*, *Ch. decipiens*, *Hemiaulus indica* and *Pleurosigma* spp. Kokubo (1934-40) reported the predominance of *Coscinodiscus* at Ohcho, Hiroshima Pref. near the present station, in early winter.

(14) St. 40 (Osaka Bay)

Total cell number is 180,000 and species number is more than twenty-four. *Thalassionema nitzschioides*, *Thalassiothrix Frauenfeldii*, and *Coscinodiscus* are dominant. The first two forms together occupy 40 %, whilst *Ch. lorenzianus*, *Ch. pseudocurvisetus*, *Eucampia zodiacus*, *Ditylum Brightwellii* and *Rhizosolenia alata* are following.

(15) St. 41-43 (Kii Channel)

Total cell number is from 18,900 (St. 41) to 101,900 (St. 43), exceptionally rich, as large as 2,970,000 cells at St. 42, and 1,017,000 in average. Species number is thirty-six. *Thalassionema nitzschioides*, *Thalassiothrix Frauenfeldii*, and *Coscinodiscus* are prevalent at St. 41 and 43; altogether the first two forms occupy above 37 %. *Chaetoceros pseudocurvisetus* is also prevalent at St. 42, occupying 67 % of the total cells. This species was reported to be a remarkable species in the inner part of Osaka Bay in December, 1952 (Ueno, 1953). The abundant diatoms at St. 42 may be associated with supply of rich nutrients from Osaka Bay which is transported to the region of St. 42 by tidal currents.

(16) St. 44 and 46 (Off Cape Muroto)

Total cell number is from 59,000 (St. 46) to 200,280 (St. 44) and 129,640 in average. Species number is forty-seven. The dominant forms are *Ch. pseudocurvisetus*, *Ch. decipiens*, *Coscinodiscus*, *Bacteriastrum*, *Thalassionema nitzschioides*, *Thalassiothrix Frauenfeldii* and *Skeletonema costatum*. The diatom associations are more or less influenced by Kuroshio water.

(17) St. 45 (Tosa Bay)

Total cell number is 135,240 and species number is twenty-five. *Thalassionema nitzschioides* (25 %), *Thalassiothrix Frauenfeldii* (17.5 %) and *Synedra* spp. (20 %) are dominant forms. *Chaetoceros pseudocurvisetus*, *Ch. didymus*, *Ch. atlanticus* v. *neapolitana* and *Skeletonema costatum* are also important constituents. Among these forms warm oceanic species number six and 5 % in cell number of total haul; neritic diatoms are rather prevalent, thus this sample shows neritic characters to a certain extent rather than the character of oceanic Kuroshio water.

(18) St. 47 (Off Kii Channel)

Diatoms are poor both in total cell number and in species number; total cell number is 8,040 and species number is nineteen. *Coscinodiscus*, *Thalassionema nitzschioides*, *Chaetoceros lorenzianus*, *Ch. decipiens*, and *Ch. coarctatus* are main constituents.

Planktoniella sol and *Gossleriella tropica* are also found. It is indicated that diatom population is fairly influenced by the Kuroshio Current. Characters of Kuroshio water as observed by diatom associations are more emphasized here than off Cape Muroto, because warm oceanic or tropical species are present to the number of 11 and occupy about 27.7 % of total cells in this station, while similar species off Cape Muroto number 12, but occupy only 5 % of total cell number.

(19) St. 48 50 (Kumano-Nada)

Diatoms are comparatively abundant in respect both to total cell number and to species number. Total cell number is between 27,500 and 333,000, averaging 224,600. Species number is fifty-one. The leading species are *Chaetoceros pseudocurvisetus* and *Skeletonema costatum*. The former species occupies above 35 % (St. 48 and 50), and the latter does 44 % (St. 49). In addition, *Ch. decipiens*, *Ch. didymus*, *Thalassionema nitzschioides* and *Nitzschia seriata* are also important forms. Marumo (1954a) reported that diatom communities were composed of *Hyalochaete*, *Rhizosolenia* and *Nitzschia seriata* in the south of Shiono-Misaki. In the present data the diatom associations off Shiono-Misaki are mainly composed of *Hyalochaete*, but show a difference from the data of Marumo (1954a) in other constituents of less importance.

(20) St. 51-57 (From Enshu-Nada to Kashima-Nada)

Total cell number is between 69,000 and 1,276,200, excluding the datum of extremely poor haul at St. 55 (2,850 cells). Average cell number is 369,000. Species number is seventy-five. The leading species are *Chaetoceros decipiens* (St. 52, 53 and 56), *Skeletonema costatum* (St. 51 and 54) and *Thalassionema nitzschioides* (St. 55). In addition, *Ch. pseudocurvisetus*, *Ch. messanensis* and *Ch. didymus* are important. According to the observations of preceding workers (Marumo, 1951; Kawarada, 1954; Asaoka, 1955), *Skeletonema costatum* is more abundant near the Miura Channel than at other localities of Sagami Bay in winter when the water of Tokyo Bay, less haline than that in Sagami Bay, flows out into the present region. A large concentration of diatoms is found at St. 52. The major constituents of this concentration are *Chaetoceros decipiens*, *Ch. lorenzianus*, *Ch. didymus*, *Ch. messanensis*, *Ch. affinis*, *Ch. compressus*, *Ch. socialis*, *Skeletonema costatum* and *Thalassionema nitzschioides*. Outflow of land drainage from the Ohi River might be suggested to be responsible for the local production of diatoms at this region. *Skeletonema costatum* is very much increased at St. 51 and 54-55, indicating the spread of coastal water to these stations, but there is an indication of some influence of Kuroshio water at St. 55 by the occurrence of *Climacodium biconcavum* (8.6 %). On the other hand, in the region extending from St. 52 to 53 the diatom associations are represented mainly by *Chaetoceros decipiens* together with

warm-water-preferring *Hyalochaete*, as was reported by Marumo (1955) off Sanriku District, in spite of the fact that surface temperature is lower than at other stations.

(21) St. 58-60 (Pacific coast of northern Honshu)

Diatoms are considerably poor in total cell number, except the abundant population at St. 60. Total cell number is 6,060 at St. 58, below 200 at St. 59 and 143,000 at St. 60, averaging 50,000. Species number is thirty-five. In the localities of poor diatoms, *Thalassionema nitzschioides*, *Thalassiosira* sp. and *Rhizosolenia Stolterfothii* are main constituents. At St. 60 *Chaetoceros Eibenii* is the most prevalent species, occupying more than a half of the diatom population, being followed by *Ch. coarctatus*, *Ch. pseudocurvisetus*, *Thalassiosira* sp., *Lauderia borealis* and *Ditylum Brightwellii*. Surface temperature falls northwards from 17.1°C at St. 58 to 14.2°C at St. 60 and 15.6°C in average. This temperature is similar to that of the area of the mixing of Kuroshio and Oyashio waters as reported by Shimomura (1953) in December. From diatom associations this region is considered to be a transitional region from warm Kuroshio water to the mixing area at the north of Kinkazan.

(22) St. 61-66 (Pacific coast of more northern Honshu)

Diatoms are poor in total cell number which ranges between 12,500 and 33,000, averaging 20,700. Species number is forty-one. Predominant species are *Coscinodiscus granii*, *C. wailesii*, *Thalassionema nitzschioides*, and *Chaetoceros affinis*. In addition, *Biddulphia sinensis*, *Hemidiscus cuneiformis*, *Stephanopyxis palmeriana* are also important constituents. *Chaetoceros*, *Thalassionema nitzschioides* and *Coscinodiscus* spp. have been reported as important components of diatoms in the Oyashio water in this region (Marumo, 1954b, 1955; Shimomura, 1953). *Chaetoceros socialis* and *Ch. debilis* are also important species to which is owed the high abundance of diatoms (Shimomura, 1953). In the present observations, *Chaetoceros* occupies from 13.3 to 37 % of total cells, increasing northwards. Associated species are commonly *Chaetoceros affinis*, *Ch. decipiens* and *Ch. didymus*, and in some localities *Ch. socialis*, *Ch. debilis*, and *Ch. convolutus*. However, *Chaetoceros* species which belong either to *Phaeoceros* or *Hyalochaete*, that have been reported as characteristic indicators of the Oyashio Current are rare in the present data. On the contrary, *Coscinodiscus* decreases in number northwards from 42.2 to 3 %. *Thalassionema nitzschioides* is remarkably dominant at St. 66, occupying more than a half of the diatom population. It is noticed that at St. 63 *Hemidiscus cuneiformis*, *Biddulphia sineisis* and *Stephanopyxis palmeriana* occupy a considerably higher portion of the population than in other localities, and also *Corethron hystrix* (11.5 %), *Ditylum Brightwellii* and *Thalassiosira* sp. occur rather often. Tamura (1951) reported similar diatom associations to the present data from Tsugaru Straits in

January, 1951.

In the present cruise the stations are located close to the coast, so that diatom associations may have been influenced by neritic waters, and, in addition, the influence of southwards warm Tsugaru Current (a tributary of Tsushima Current) from Tsugaru Straits flowing in the comparatively inshore area and that of northwards cold Oyashiwo Current in the offing are mixed to a certain extent, exerting influence upon the associations of diatoms in the present stations.

IV. Discussion

It is still a perplexed matter to decide what plankton forms should be selected for indicating what nature of water, though accumulated works have contributed to generalize the ecological situation of the various forms in relation to the environmental characteristics, especially to the temperature of habitat, and in less completeness to the salinity.

Ocean currents may be evidently traced by the existence of most intolerant oceanic species which are transported by the current from their original propagative area. However, strictly intolerant forms, if they occur, are usually present in very small number out of their birth place; in most cases their presence or absence is only recorded, and the difficulty in accurate numerical expression is often involved. On the other hand, there is no evidence, in phytoplanktons, that they do not reproduce in favorable circumstances wherever during their drift, so that even though a large concentration of such forms is found in some locality out of their original area, it does not necessarily indicate the prevalence of the current itself in this locality.

It is known that the characterization of plankton associations obtained from one place cannot be adopted for other localities; a species associating with a particular nature of water does not always do so in water of similar nature in other regions. It is natural that, for instance, some of the neritic species which widely inhabit the tropics or subtropics might be drifted with the current toward a high latitude with resistance to the changing environments; thus they would become apparent indicators of oceanic warm current in high latitude. *Chaetoceros lorenzianus* and *Ch. distans* are such forms which are considered to be indicators of the Tsushima Current in northern Japan. Such regionality of plankton characteristics forces planktologists to make more efforts in charting the characteristic associations at various localities in various seasons in as great detail as possible.

The greatest usefulness of plankton indication of water masses would be involved in the ascertainment of mixing rate of two or more water masses of different nature, *e. g.*, oceanic and neritic water, or warm and cold current, with an accuracy that physical, or even chemical, determination would not be able to manifest.

Many preceding workers have presented accounts of diatom associations on the coast and in the offing of Japan, discussing their characteristics which apparently associate with the water masses in which they are distributed. However, differences in times and

positions of samplings from the present observations, though in some cases to a very slight extent, make it difficult to make reference to the earlier reports or comparison with them. So far as possible to summarize the present data the knowledge accumulated by the many preceding authors is adopted for classifying the plankton forms into warm or cold and oceanic or neritic preference, though some should be valued as tentative decisions.

In the present observations, the track of the ship along the Japan Sea coast of Honshu was populated by such tropical or subtropical species as *Chaetoceros coarctatus*, *Climacodium Frauenfeldianum* and *C. beconcavum*. Even in the region near the coast, tropical diatoms such as *Chaetoceros diversus*, *Ch. paradoxum* and *Ch. messanensis* were prevalent. Along the track on the coast of Kyushu neritic species, viz., *Skeletonema costatum*, *Asterionella japonica* and *Eucampia zoodiacus* were most prevalent forms among the population. *Thalassionema nitzschioides* was widely distributed covering the area from Osaka Bay to Kii Channel. *Skeletonema costatum* which is known as a wide spread species and as making remarkable increase in certain neritic conditions occurred in large number on the Pacific coast from Kii Peninsula to Boso Peninsula. *Climacodium biconcavum* was found frequently in certain areas of the Pacific coast reflecting the presence of Kuroshio water. In such area the total cells were comparatively decreased. The area in which predominance of *Chaetoceros pseudocurvisetus* was found was also considered to be bathed with Kuroshio water. In the coastal region of the Pacific side occurrence of *Planktoniella sol*, *Coscleriella tropica*, *Guinardia flaccida*, *Hemiaulus indica*, *Chaetoceros coarctatus* and *Ch. atlanticus* v. *neapolitana*, though in comparatively small number, indicated that there the water was mixed with Kuroshio water to a certain extent. The diatom population off Cape Omae-Zaki (St. 52) was composed of *Chaetoceros decipiens* and warm-water-preferring *Hyalochaete*. This probably reflects the effects of lowering temperature. On the northern coast of Honshu on the Pacific side the track of the ship covered a region of coastal water embodying the *Chaeto*-plankton, but the flow of Oyashio is reflected in the occurrence of cold-water-preferring *Hyalochaete*, such as *Chaetoceros decipiens*, *Ch. debilis*, *Ch. socialis*, *Ch. convolutus* and *Corethron hystrix*. The prevalence of *Chaetoceros Eibenii* at St. 60 suggested that there is mixing of the Oyashio water with the Kuroshio water.

V. Summary

The materials of diatoms were collected by underway samplings aboard the "Oshoro Maru" during her round-Japan cruise from October 14 to December 15, 1952.

Diatom associations in neritic region along Japan Sea coast are mainly composed of *Chaeto*-plankton; warm-water *Hyalochaete*, *Rhizosolenia* and *Thalassionema nitzschioides*, while in the offings *Chaetoceros coarctatus* and *Climacodium* are prevalent, though the above mentioned neritic forms are also included.

On the northwest coast of Kyushu, *Eucampia zoodiacus* and *Hyalochaete* are predominant, and on the west coast, such neritic diatoms as *Skeletonema costatum*, *Asterionella japonica* and warm-water *Hyalochaete* are abundantly collected.

In Kagoshima Bay on the south coast of Kyushu, warm-water *Hyalochaete* and *Thalassionema* are dominant, and other forms even more preferring warm-water are found, indicating the direct influence of the Kuroshio Current.

Diatom associations in the Inland Sea are different from those in other localities; *Coscinodiscus* is prevalent, occupying half or more of total diatom population.

Thalassionema nitzschioides, *Thalassiothrix Frauenfeldii* and *Coscinodiscus* are dominant in the area from Osaka Bay to Kii Channel; in addition, *Chaetoceros pseudocurvisetus* is abundantly distributed off Wakayama.

From off Cape Muroto to Tosa Bay, the above forms also occurred prevalently, and in addition, several other warm-water diatoms are found together, indicating the influence of Kuroshio water.

Characteristic Kuroshio diatoms, *e. g.*, warm-water *Hyalochaete* and other several tropical forms, prevail in the offing of Kii Channel, but *Chaetoceros decipiens* is also there abundantly included.

Skeletonema costatum and *Ch. pseudocurvisetus* and other neritic diatoms are dominant on the east coast of the Kii Peninsula.

Either *Skeletonema costatum* or *Hyalochaete* and *Ch. decipiens* are leading forms in the area extending from Enshu-Nada to Kashima-Nada; the former may be the indicator species of prevalent coastal water.

On the Pacific coast of northern Honshu, *Chaetoceros Eibenii* and other *Chaetoceros* spp. are dominant to the south of Kinkazan, but in other localities, diatoms are extremely poor, represented by such forms as *Thalassionema nitzschioides*, *Rhizosolenia* and *Thalassiosira*.

On the more northern coast of Honshu, *Coscinodiscus*, *Thalassionema*, *Chaetoceros affinis*, and *Ch. decipiens* are dominant. Only a few cold species of *Hyalochaete* and *Coscinodiscus* are collected there.

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