

Seasonal Changes in Flux and Species Composition of Diatoms: Sediment Trap Results from the Northwest Pacific, August 1986–November 1988

By

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Abstract Three sets of a time-series of thirteen consecutive 18 to 21 day-long samples, representing three sediment trapping intervals, August 1986–May 1987, June 1987–February 1988 and March–November 1988, were collected from the northwest Pacific ($34^{\circ}10.1' - 34^{\circ}11.3'N$, $141^{\circ}57.7' - 141^{\circ}59.53'E$), and provided material to evaluate seasonal changes in both flux and species composition of diatoms. Five high flux periods corresponding to a spring or autumn phytoplankton bloom occurred in the time-series flux records for the three sediment trapping intervals. Four minor peaks in total diatoms were also recorded in the flux, which may be related to high diatom production associated with a large amount of nutrient-rich river supply to coastal waters during the rainy season, or with a local upwelling caused by northerly wind blowing from Siberia in winter. Temporal changes in the path of the Kuroshio, lateral and vertical water movements in the water column, and a corrosion-related decrease in relative abundances of weakly silicified forms were also discriminated as flux controlling factors. In 39 sediment trap cup samples, 136 diatom species or varieties belonging to 55 genera were identified. In the trapping intervals, a nearly uniform seasonal succession of dominant forms occurred, which may be partly due to the intermixture and/or dispersion of particulate materials during their sinking from the euphotic realm to the sediment trap deployed at deep water. High abundances of *Nitzschia bica pitata*–*N. bifurcata* complex, *Thalassionema nitzschioides* and *Neodelphineis indica* characterize all the trapped assemblages.

Introduction

Finding from sediment trap experiments provide information to down-core study when paleoceanographical signals preserved in sediments are interpreted in detail (*e. g.* THUNELL and REYNOLDS, 1984; GERSONDE and WEFER, 1987; LEVENTER and DUNBER, 1987. SAUTTER and SANCETTA, 1992). The knowledge about the flux of organic materials produced in the Kuroshio (STOMMEL and YOSHIDA, 1972) is, in particular, important for the reconstruction of oceanographic history of the northwest Pacific.

To examine seasonal changes in flux of lithogenic and biogenic materials, an automated time-series sediment trap has been deployed at Pacific Station JT by Woods Hole Oceanographic Institution and the Ocean Research Institute, University of Tokyo, since August 1986 (Fig. 1). The mooring site JT is situated within the Kuroshio Area, where the Kuroshio flows northward with inner colder and less saline, and

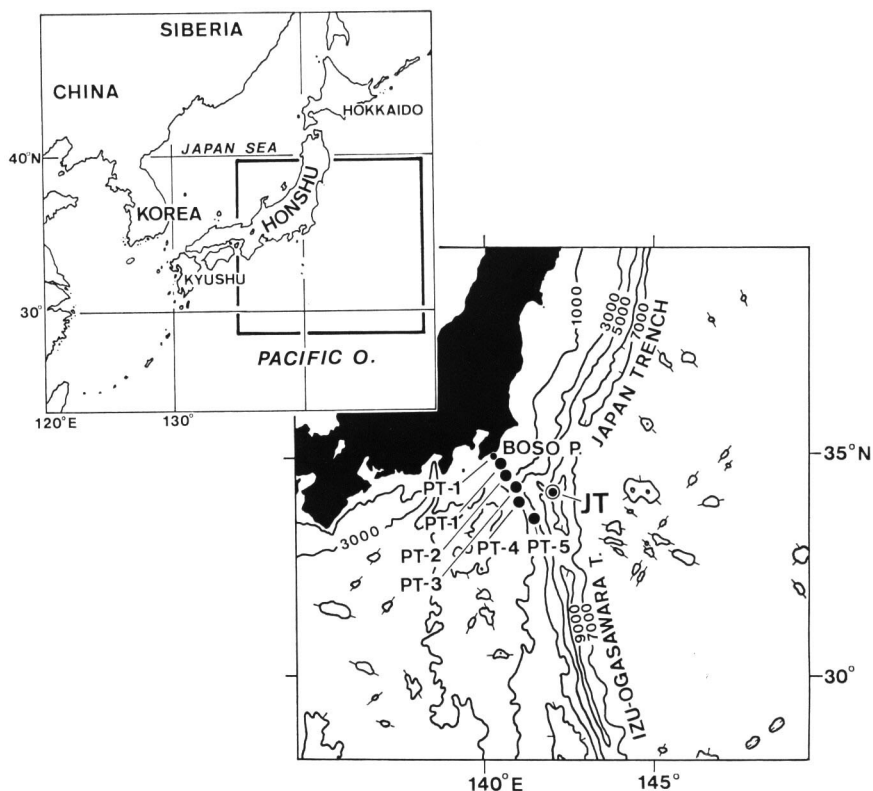


Fig. 1. Location of sediment trap moorings (JT) and Japan Meteorological Agency's Oceanographic Stations (PT-1 to -5). Bathymetric contours are shown in meters (bathymetry after Mogi, 1972).

outer colder watermasses (KAWAI, 1972). Hydrographic changes at the site are controlled by the large and long-lived meander of the Kuroshio (SHOJI, 1972; Japan Meteorological Agency 1986–1988, Fig. 2). In the euphotic zone overlying the sediment trap, temperature, salinity and nutrient supply cycles are partly depending on the fluctuations of the meander, which subsequently vary diatom production. Diatom abundance is higher in the inner less saline water than in the Kuroshio water (UYENO, 1957). Multi-year plankton collecting program, which has been monitoring seasonal variations in both diatom abundance and specific composition at Japan Meteorological Agency's Oceanographic Stations, PT-1 to -5, also show the same tendency (Japan Meteorological Agency 1988–1990; Fig. 3).

Acquisition of sediment trap samples at Station JT allows me to examine seasonal variations in the production and transportation of modern species of diatoms as a function of changing hydrography in this region. In this paper, I have described the initial two-year data on diatom flux, also related them to known oceanographic

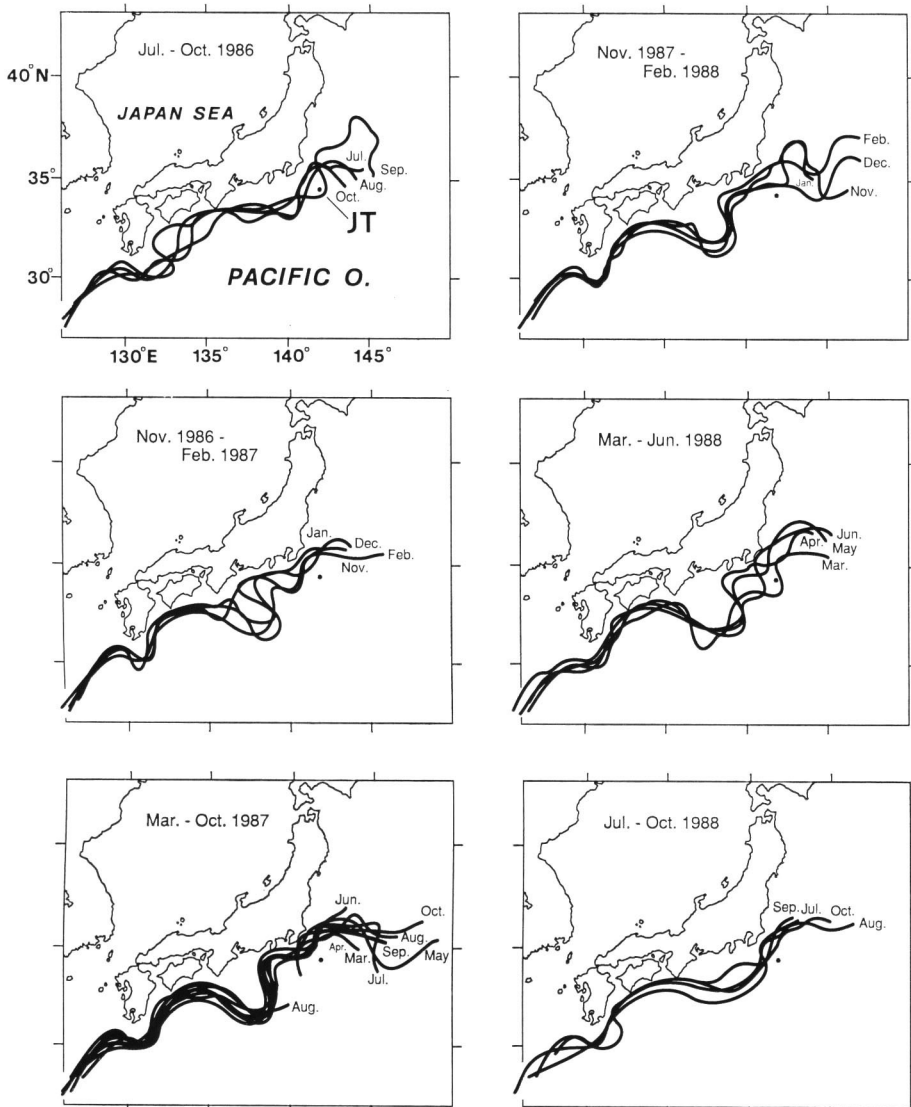


Fig. 2. Path of the Kuroshio, July 1986 through October 1988. The path data is from Japan Meteorological Agency (1986–1988).

processes in the region.

Material and Methods

A total of 39 samples, representing three sediment trapping intervals, was collected at Station JT (Appendix 1). The trap used in this study is an automated Mark

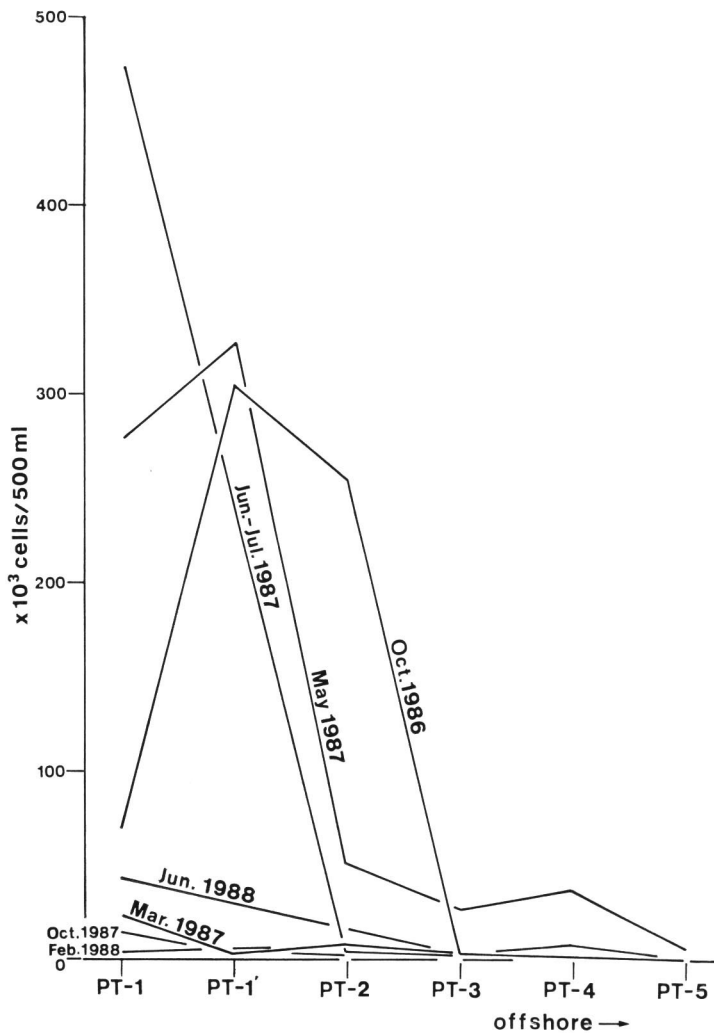


Fig. 3. Cell concentrations of diatoms in 500 ml of sea surface water at six oceanographic stations of the Japan Meteorological Agency (Japan Meteorological Agency 1988–1990).

VI time-series sediment trap (HONJO and DOHERTY, 1988), which is designed to collect a set of thirteen consecutive 18 to 21 day-long samples.

Larger particles like fecal pellets or pteropods were removed from each trapped material with a plastic 1 mm screen, then each trap cup sample was split into aliquots for special investigations (in Kaiyo Monthly, No. 124, 1989) with a splitter.

Each sample preserved with a mixture of acetic acid and formalin (1:1) was diluted with distilled water to obtain a suspension of proper density. For permanent

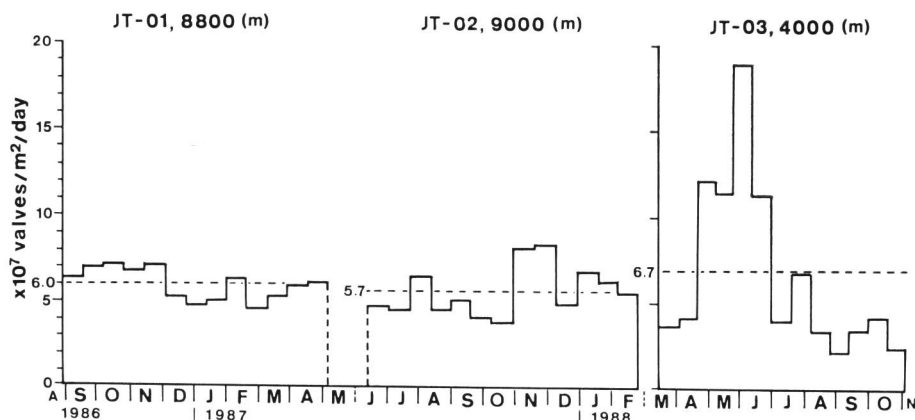


Fig. 4. Seasonal flux records of total diatoms.

slide preparation, the suspension was filtered with $0.8 \mu\text{m}$ Millipore filter (Type AA) for desalting. The filter was gently washed with distilled water to remove any adhering diatom cells, then a 0.5 ml of the diluted suspension was taken by the aid of a micropipette with a disposable plastic tip, and was placed on a cover glass. After drying at room temperature for 24 hours, it was mounted on a slide glass with Hyrax. Observation and identification of diatoms were made at 1250 x with Nomarskii differential interference contrast.

Counts of both absolute diatom flux and relative species abundance in a flora were performed on each trap cup sample. Relative species abundance was estimated by counting over 500 valves while traversing a slide under a light microscope at 1250 x, and absolute flux was determined by scanning several transects of a slide at 1250 x, until 3000–5000 specimens had been counted. The definition of counting units follows that of SCHRADER and GERSONDE (1978).

Results

Diatom fluxes

Total diatom flux ranges from 3.85×10^7 to 1.9×10^8 valves/ m^2 /day, with average values of 6.14×10^7 valves/ m^2 /day (Fig. 4). Time-series flux records for JT-01 to -02 and JT-03 show larger difference in the magnitude of fluctuation. Late spring peak, late April–June 1988, occurred in JT-03 is distinct, whereas spring and autumn peaks in JT-01 to -02, September–November 1986, March–early May 1987, November–early December 1987 and September–October 1988, are less distinct. In addition, several minor peaks in total diatom flux occurred consistently from year to year in the summer or winter months; February 1987, late July–early August 1987, January–early February 1988 and late July–early August 1988.

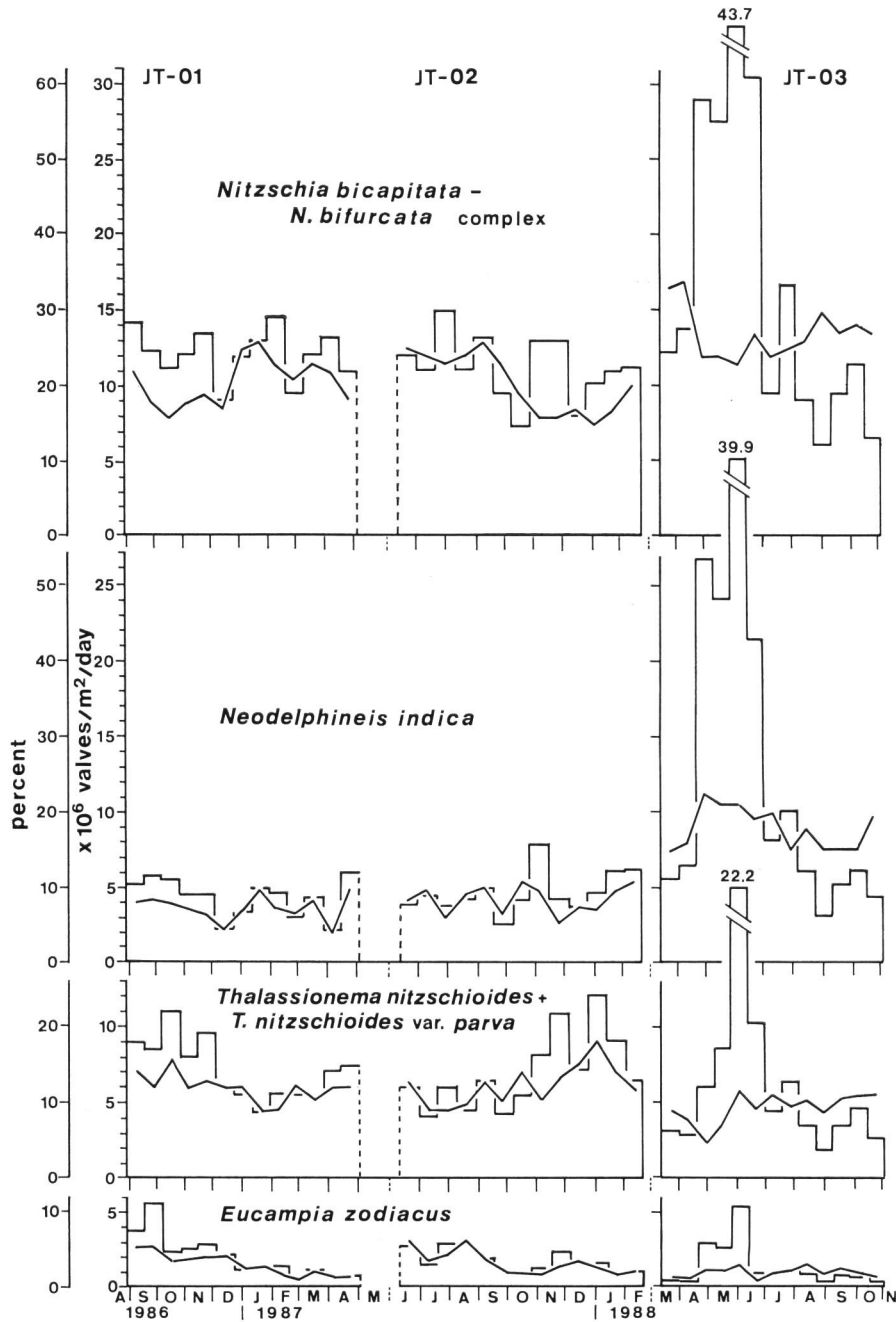


Fig. 5. Seasonal changes in both absolute fluxes (column plots) and relative abundances (line plots) of dominant forms.

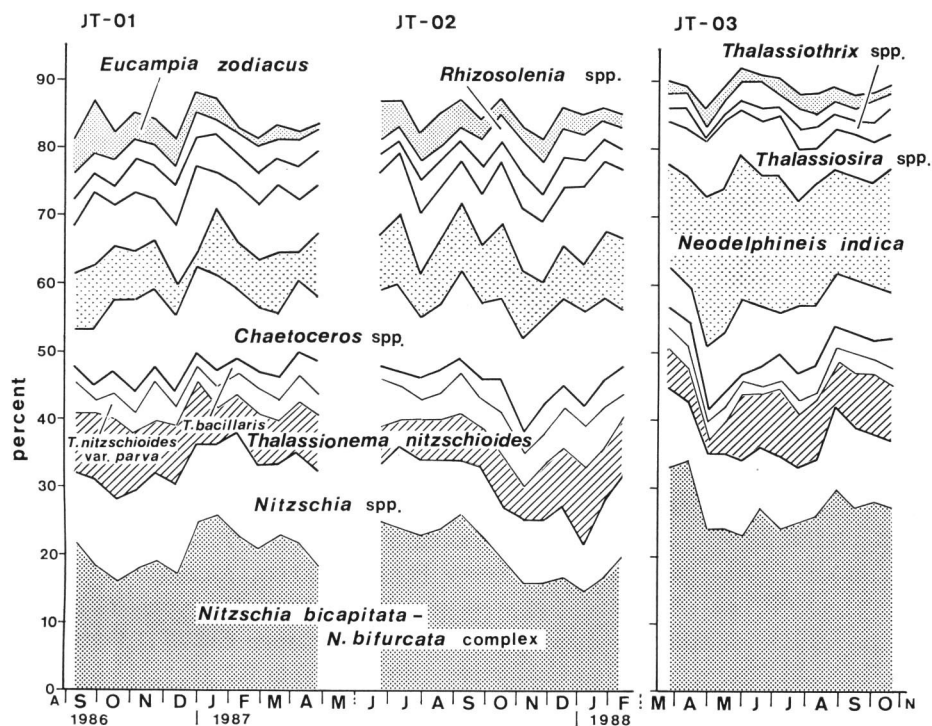


Fig. 6. Cumulative percentages of common taxa of diatoms for the sediment trap samples from Station JT.

In 39 sediment trap cup samples, 136 diatom taxa were identified (Appendix 2). Since the spectrum of diatom species found in the three sediment trapping intervals is rather uniform, seasonal flux pattern for each dominant form is similar to that for total diatoms. *Nitzschia bicapitata* CLEVE-*N. bifurcata* KACZMARSKA et LICEA complex is the most significant contributor to the total diatom flux. The maximum flux of the complex occurred during April-June 1988 with a value of 4.37×10^7 valves/m²/day. For the remainder of the three trapping intervals, the fluxes of the complex range from 7 to 15×10^6 valves/m²/day in JT-01 to -02 and from 6 to 17×10^6 valves/m²/day in JT-03, with no evident seasonality (Fig. 5).

Maxima in fluxes of other four dominant forms, *Neodelphineis indica* (TAYLOR) TANIMURA, *Thalassionema nitzschioides* GRUNOW, *T. nitzschioides* var. *parva* HEIDEN and *Eucampia zodiacus* EHRENBERG, also occurred during the same late spring-early summer months of 1988 with values of 3.99×10^7 valves/m²/day for *N. indica*, 2.22×10^7 valves/m²/day for *T. nitzschioides* including *T. nitzschioides* var. *parva*, and 5.56×10^6 valves/m²/day for *E. zodiacus*. *Neodelphineis indica* and *T. nitzschioides* including *T. nitzschioides* var. *parva* have two or three minor peaks in their fluxes during the

autumn–early winter of 1986 through 1988 ranging from approximately 5 to 12×10^6 valves/m²/day. Flux rates for other forms are low, reaching maximum value of 6×10^6 valves/m²/day, and there is no significant seasonality in the flux.

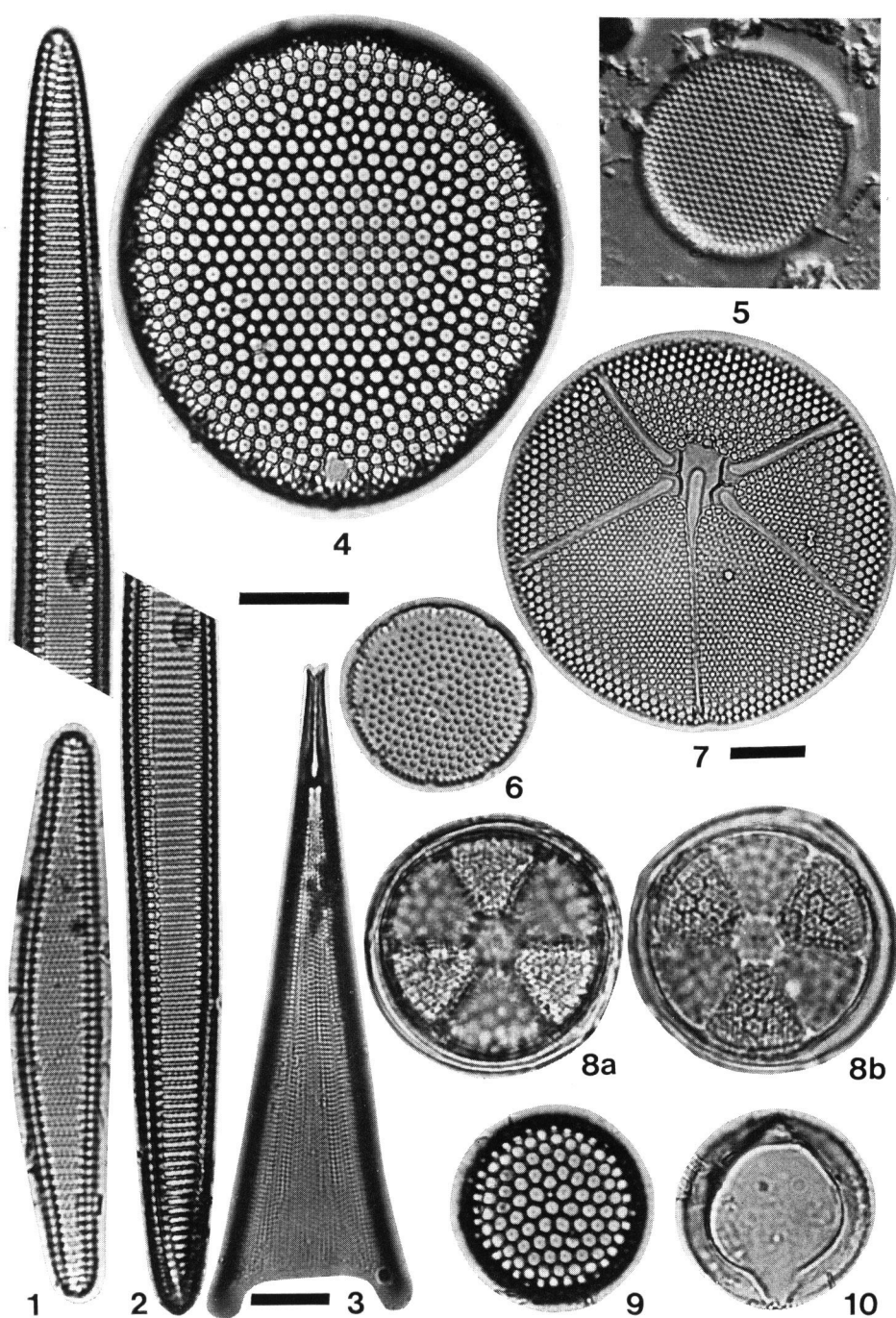
Diatom Assemblages

All samples studied are dominated by large to very large numbers of *Nitzschia*, *Thalassionema*, *Chaetoceros*, *Neodelphineis*, *Thalassiosira*, *Thalassiothrix*, *Rhizosolenia* and *Eucampia* species (Fig. 6). Fourteen forms belonging to eight genera, *Nitzschia bicaipitata*–*N. bifurcata* complex, *Thalassionema nitzschioides*, *T. nitzschioides* var. *parva*, *Thalassionema bacillaris* (HEIDEN) KOLBE, *Chaetoceros lorenzianum* GRUNOW, *Chaetoceros messanense* CASTRACANE, *Chaetoceros diciptiens* CLEVE, *Neodelphineis indica*, *Thalassiosira oestrupii* (OSTENFELD) PROSKINA-LAVRENKO, *Thalassiosira lineata* JOUSÉ, *Thalassiothrix frauenfeldii* GRUNOW, *Rhizosolenia setigera* BRIGHTWELL and *Eucampia zodiacus*, together comprise over 51%, and up to 69% of each diatom assemblage. *Azpeitia tabularis* (GRUNOW) FRYXELL et SIMS, *Chaetoceros pseudocurvisetum* MANGIN, *Chaetoceros sociale* LAUDER, *Hemiaulus sinensis* GREVILLE, *Nitzschia marina* GRUNOW, *Nitzschia sicula* (CASTRACANE) HUSTEDT, *Pseudoeunotia doliolus* (WALLICH) GRUNOW, *Rhizosolenia bergonii* H. PERAGALLO, *Rhizosolenia imbricata* var. *shrubslei* (CLEVE) SCHRÖDER, *Roperia tessellata* (ROPER) GRUNOW, *Thalassiosira decipiens* (GRUNOW) JØRGENSEN, and *Thalassiothrix longissima* CLEVE et GRUNOW are also present in most of the trapped samples, ranging from 0.2 to 3.5% in each assemblage.

In addition to these forms, subpolar diatoms such as *Neodenticula seminae* (SIMONSEN et KANAYA) AKIBA et YANAGISAWA (= *Denticulopsis seminae* (SIMONSEN et KANAYA) SIMONSEN), *Odontella aurita* (LYNGBYE) AGARDH and *Thalassiosira nordenskiöldii* CLEVE are also present in the samples, ranging from 0.5 to 4% in each trapped assemblage, probably owing to cold-water upwelling in the Kuroshio Area. Moreover, the presence of non-marine and fossil taxa in the trapped assemblages may be a result of admixture of suspended terrestrial material. Their percentages range from 0.2 to 0.5% with no seasonality.

Nitzschia bicaipitata–*N. bifurcata* complex is the most abundant constituent of the trapped assemblage. It occupies 15 to 26% of the whole assemblage in JT-01 to -02 and from 23 to 34% in JT-03. Temporal changes in percentage contribution of the complex to the total diatom flux show seasonality. Relative decrease of the complex occurred in September–early December 1886, October–January 1987 and April–June 1988, and each decrease is followed by a relative increase in the winter or summer

Fig. 7. 1, *Pseudoeunotia doliolus* (WALLICH) GRUNOW, JT-01–3. 2, *Nitzschia marina* GRUNOW, JT-01–13. 3, *Rhizosolenia bergonii* H. PERAGALLO, JT-01–3. 4, *Roperia tessellata* (ROPER) GRUNOW, JT-01–3. 5, *Thalassiosira lineata* JOUSÉ, JT-01–3. 6, *Azpeitia tabularis* (GRUNOW) FRYXELL et SIMS, JT-01–3. 7, *Asteromphalus arachne* (BRÉBISSE) RALFS, JT-01–3. 8a and b, *Actinopteryx senarius* EHRENBERG, JT-01–3. 9 and 10, *Thalassiosira oestrupii* (OSTENFELD) PROSKINA-LAVRENKO, JT-01–3. (Scale bar = 10 μ m)



months (Fig. 5). As compared with the complex, *Thalassionema nitzschioides* including *T. nitzschioides* var. *parva* shows relative increase in abundance during the autumn–winter of 1986 through 1988, and *Neodelphineis indica* shows an evident increase in percentage contribution of the species to the total diatom flux during April–July 1988. Relative abundances of other common to rare forms seem to show no detectable seasonality because of their scarcity.

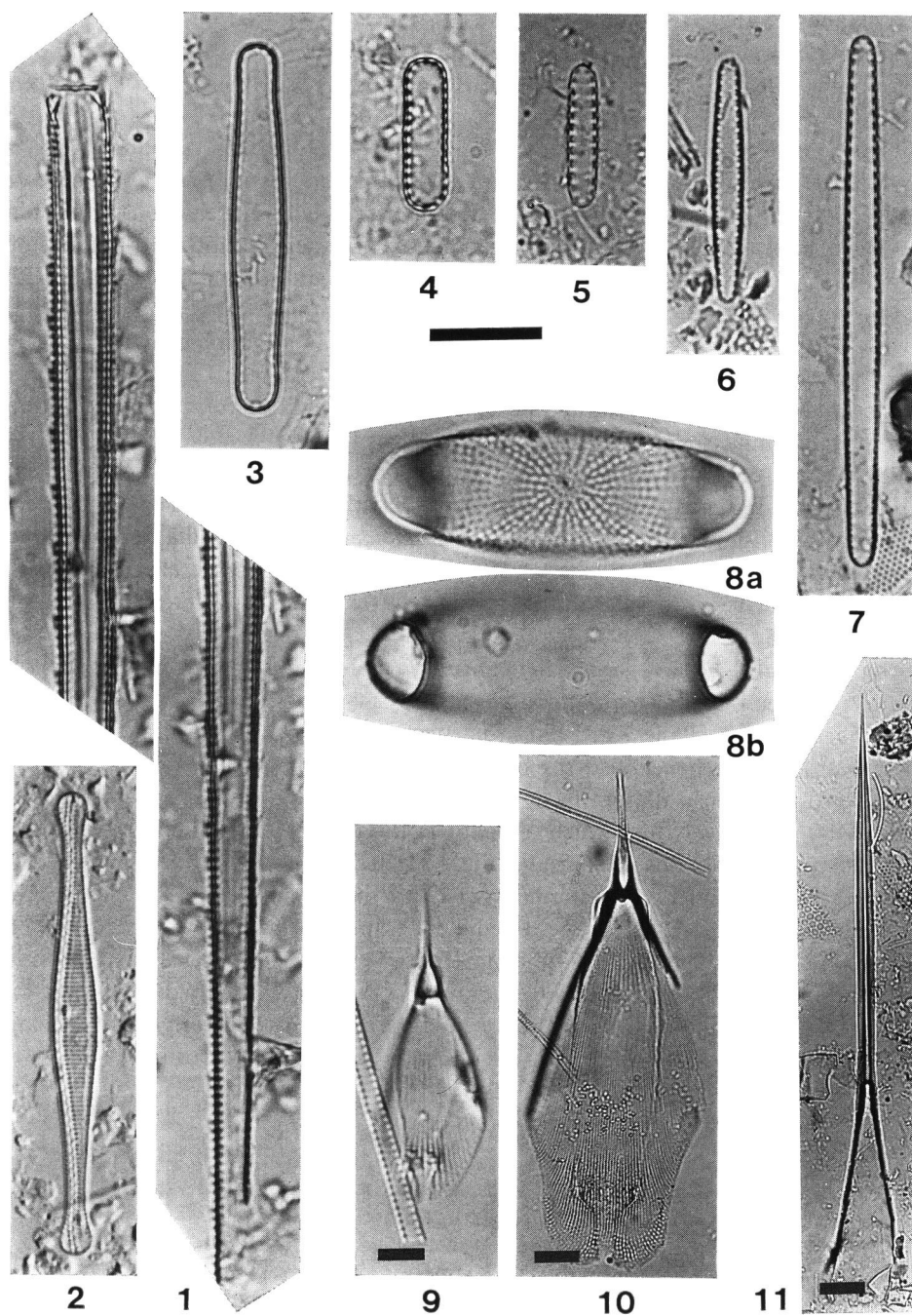
Discussion

Seasonal variations in the total diatom flux may be primarily controlled by temporal changes in primary productivity. One distinct spring peak in JT-03 and four other less distinct peaks occurring during the spring or autumn months may correspond to the typical bimodal pattern of diatom production in temperate waters (SMAYDA, 1966). Several minor peaks occurring consistently in the summer or winter months may reflect relatively high diatom production caused by a large amount of nutrient-rich river supply to coastal waters in the rainy season, or by a local upwelling associated with northerly winds blowing from Siberia in winter.

The total diatom flux patterns show significant difference in fluctuation between the sediment trapping intervals JT-01 to -02 and JT-03. Magnitude in fluctuation of the total diatom flux in JT-03 is almost three times as large as that of the total flux in JT-01 to -02. This difference may be partly caused by a modification of diatom assemblages both in the water column and around the trap. Both lateral and vertical water movements are present throughout the water column, and these movements intermix and/or disperse the particulate material which is sinking from the euphotic realm to the trap. The trapping intervals JT-01 to -02 were hence probably much influenced, as compared to the trapping interval JT-03, by both lateral and vertical water movements in the water column, while little is known about the intermixture or dispersion of particulate material around a trap. Further study will reveal to what extent both lateral and vertical water movements in the water column modify the composition of biogenic materials during their sinking from the euphotic zone to a sediment trap.

In all the trapped assemblages studied, four diatom species, *Nitzschia bica pitata*–*N. bifurcata* complex, *Thalassionema nitzschioides* and *Neodelphineis indica*, dominate. In other words, a distinctive seasonal succession in specific association of dominant forms did not occur throughout the trapping intervals. Such uniformity in seasonal floral changes has not previously been reported from sediment trap collections in

Fig. 8. 1, *Thalassiothrix longissima* CLEVE et GRUNOW, JT-01–7. 2, *Nitzschia capuluspalae* SIMONSEN, JT-01–3. 3, 5, and 7, *Thalassionema nitzschioides* GRUNOW, JT-01–3. 4, *Thalassionema nitzschioides* var. *parva* HEIDEN, JT-01–13. 6, *Thalassionema nitzschioides* GRUNOW, JT-01–13. 8, *Eucampia zodiacus* EHRENBURG, JT-01–13. 9, *Rhizosolenia imbricata* var. *shrubsolei* (CLEVE) SCHRÖDER, JT-01–13. 10, *Rhizosolenia styliformis* BRIGHTWELL, JT-01–3. 11, *Rhizosolenia setigera* BRIGHTWELL, JT-01–3. (Scale bar = 10 μ m)

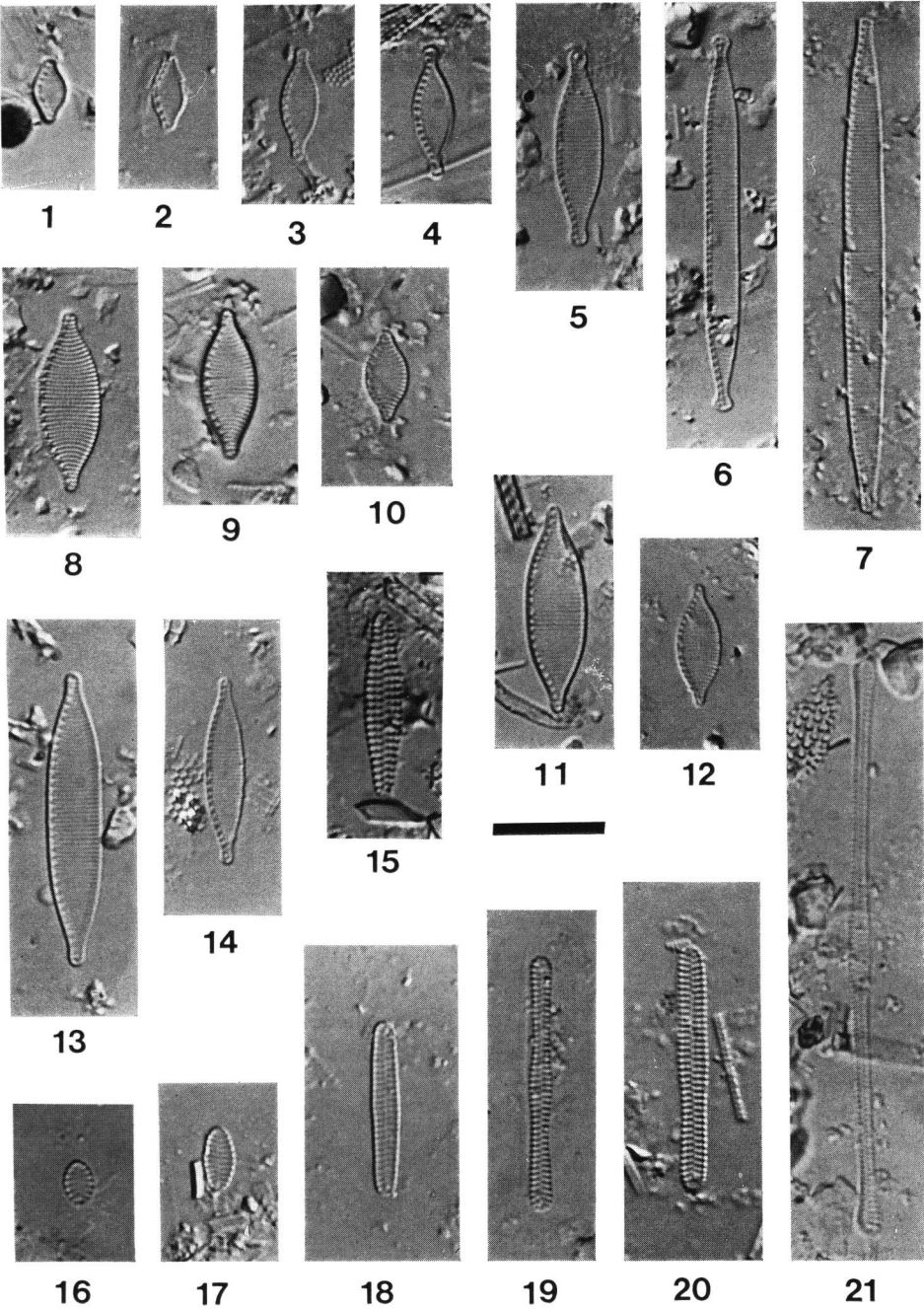


other regions of the Pacific (TAKAHASHI 1986, SAUTTER and SANCETTA, 1992), and is remarkably characteristic of the trapped diatom assemblages of this region, although the trapping depth, as mentioned above, is probably one of the reason for the uniformity.

Trapping depth has also effect on a dissolution which may modify diatom assemblages in the water column. Since the three sediment trapping intervals cover different seasons, a strict comparison between the diatom assemblages for each of the trapping intervals is difficult. Between JT-01 to -02 and JT-03, there is, however, a noticeable difference in percentage contribution of dominant forms to the total diatom flux. The average percentage contribution of *Neodelphineis indica* for JT-03 is almost two times as large as that of the species for JT-01 to -02. The same difference is found in the percentage contribution of *N. bicapitata*-*N. bifurcata* complex. This difference in relative abundances may primarily due to dissolution of these forms during settling. Both *N. indica* and *N. bicapitata*-*N. bifurcata* complex are weakly silicified and are probably easily corroded by sea water in the water column. These three forms are rarely found in sediments, which is consistent with this inference. The fact that the percentage contribution of *Thalassionema nitzschioides* to the total diatom flux, which is corrosion resistant, does not show significant decrease with depth also supports the inference, and hence corrosion of weakly silicified forms in the water column may be a flux controlling factor.

As mentioned earlier, seasonal changes in diatom abundance in the euphotic zone of this area relate to temporal changes in surface water hydrography in general, and to the meander of the Kuroshio in particular. Temporal variations in the path of the Kuroshio are hence also the oceanographic factor which may be responsible for seasonal changes in diatom flux. In waters overlying the sediment trap, diatom productivity is relatively high when the path of the Kuroshio shifts offshore from the southeast coast of the Boso Peninsula (Figs. 2 and 3). In other words, an offshore shift of the Kuroshio from the southeast coast of the peninsula leads to the covering of the high productive water over the sediment trap. Such long-lived offshore shifts occurred around September 1986 and March 1988 (Fig. 2). It seems that the maximum diatom flux during the spring months of 1988 and a high diatom flux rate during the autumn months of 1986 may be partly due to the overlying of the high productive waters in association with the offshore shifts of the Kuroshio.

Fig. 9. 1-7 and 11-14, *Nitzschia bicapitata* CLEVE emend. KACZMARSKA et FRYXELL; 1 and 5, JT-01-7; 2, 3 and 12, JT-01-4; 4, JT-01-11; 6 and 14, JT-01-1; 7, JT-01-3; 11, JT-01-8; 13, JT-01-12. 8-10, *Nitzschia bifurcata* (?) KACZMARSKA et FRYXELL; 8, JT-01-1; 9, JT-01-12; 10, JT-01-7. 15, *Neodelphineis pelagica* TAKANO, JT-01-11. 16-21, *Neodelphineis indica* (TAYLOR) TANIMURA, nov. comb.; 16, 18 and 21, JT-01-3; 17 and 19, JT-01-12; 20, JT-01-13. (Scale bar = 10 μ m)



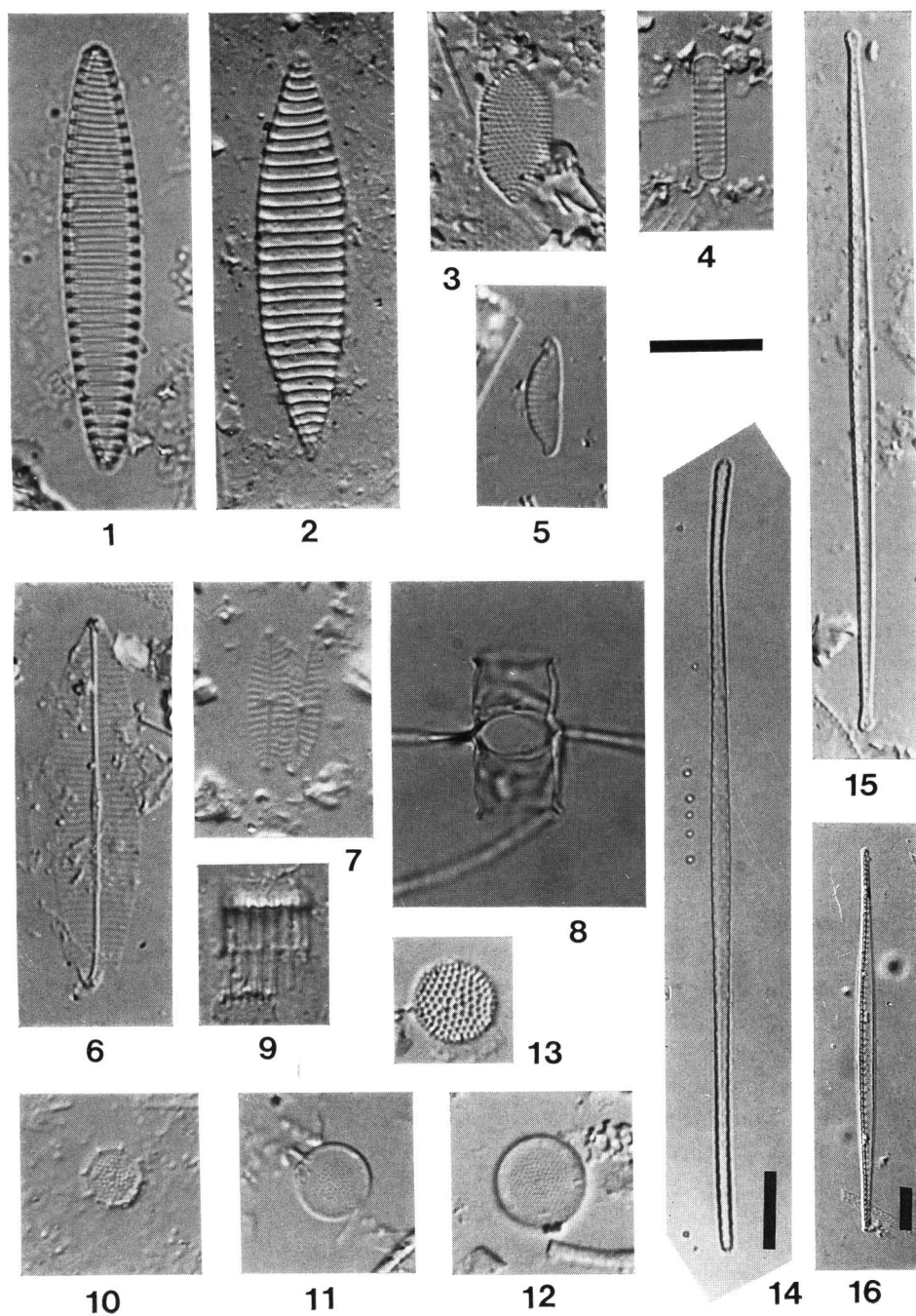
Concluding Remarks

Several preliminary findings on diatom flux can be drawn from the initial two-year data collected from the sediment trap experiment at Pacific Station JT. Nine high flux periods were recorded in the time-series flux. One distinct and four less distinct peaks occurring in the spring or autumn months may correspond to the typical bimodal pattern of diatom production in temperate waters, and four minor peaks probably reflect high diatom production associated with a nutrient-rich river supply during the early summer months, or with a local upwelling in the winter months. In a time-series of 39 sediment trap cup samples, 136 diatom taxa were identified. *Nitzschia bicaipitata*-*N. bifurcata* complex, *Thalassionema nitzschioides* and *Neodelphineis indica* are dominant, and ten forms, *Thalassionema nitzschioides* var *parva*, *T. bacillaris*, *Eucampia zodiacus*, *Chaetoceros lorenzianum*, *C. messanense*, *C. diciptiens*, *Thalassiosira oestrupii*, *T. lineata*, *Thalassiothrix frauenfeldii*, *Rhizosolenia setigera*, are common to rare in most samples. These fourteen forms together comprise over 51%, and up to 69% of each diatom assemblage. The spectrum of diatom species found in the sediment trapping intervals is rather uniform except for a slight increase in relative abundances of *T. nitzschioides* and/or *N. indica* during the time of high flux rates probably associated with a spring or autumn phytoplankton bloom, and except for a decrease of *Nitzschia bicaipitata*-*N. bifurcata* complex in the same period. A depth-related modification of diatom assemblages in the water column and temporal changes in the path of the Kuroshio were also found to be flux controlling factors.

Taxonomic Notes

Floral composition is tabulated for each sediment trap cup sample studied (Appendix 2). Unidentified and important forms are alphabetized and illustrated. Several species belonging to *Cerataulina*, *Chaetoceros*, *Guinardia*, *Nitzschia* and *Thalassiosira* having delicate valves could not be identified because of their dissolved, broken and/or fragmental nature of valves. They were bundled into "spp." or "others" in the appendix. The five most common diatoms are herein listed with remarks; A new combination has been made. All the permanent slides have been deposited in the micropaleontological reference collection of the National Science Museum, Tokyo: MPC 04916-04954.

Fig. 10. 1, *Nitzschia sicula* (CASTRACANE) HUSTEDT, JT-01-3. 2, *Nitzschia sicula* var. *bicuneata* HASLE, JT-01-3. 3, *Nitzschia* sp. b, JT-01-3. 4, *Nitzschia cylindrus* GRUNOW (HASLE), JT-01-8. 5, *Amphora* sp. a, JT-01-1. 6, *Navicula* sp. a, JT-01-13. 7, *Navicula* sp. b, JT-01-12. 8, *Chaetoceros* sp. a, JT-01-3. 9, *Skeletonema costatum* (GREVILLE) CLEVE, JT-01-3. 10, *Thalassiosira* sp., JT-01-3. 11, *Thalassiosira* sp. a, JT-01-3. 12, *Thalassiosira* sp. c, JT-01-13. 13, *Thalassiosira* sp. b, JT-01-10. 14, *Thalassionema bacillaris* (HEIDEN) KOLBE, JT-01-3. 15, *Nitzschia* sp. c, JT-01-3. 16, *Nitzschia* sp. a, JT-01-3. (Scale bar = 10 μ m)



Eucampia zodiacus EHRENBURG; HUSTEDT, 1930, p. 772, fig. 451; HENDEY, 1964, p. 107, pl. 7, fig. 1.

Lightly silicified vegetative cells of this taxon were often found in spiral colonies. Examined specimens have perivalvar axis of 6–20 μm , with widths of 25–65 μm . Valve face is finely striated, 14–18 in 10 μm . (Figs. 8–8a and –8b)

Neodelphineis indica (TAYLOR) TANIMURA, nov. comb.

Basionym: *Synedra indica* TAYLOR, 1966, p. 440, pl. 3, figs. 22–24.

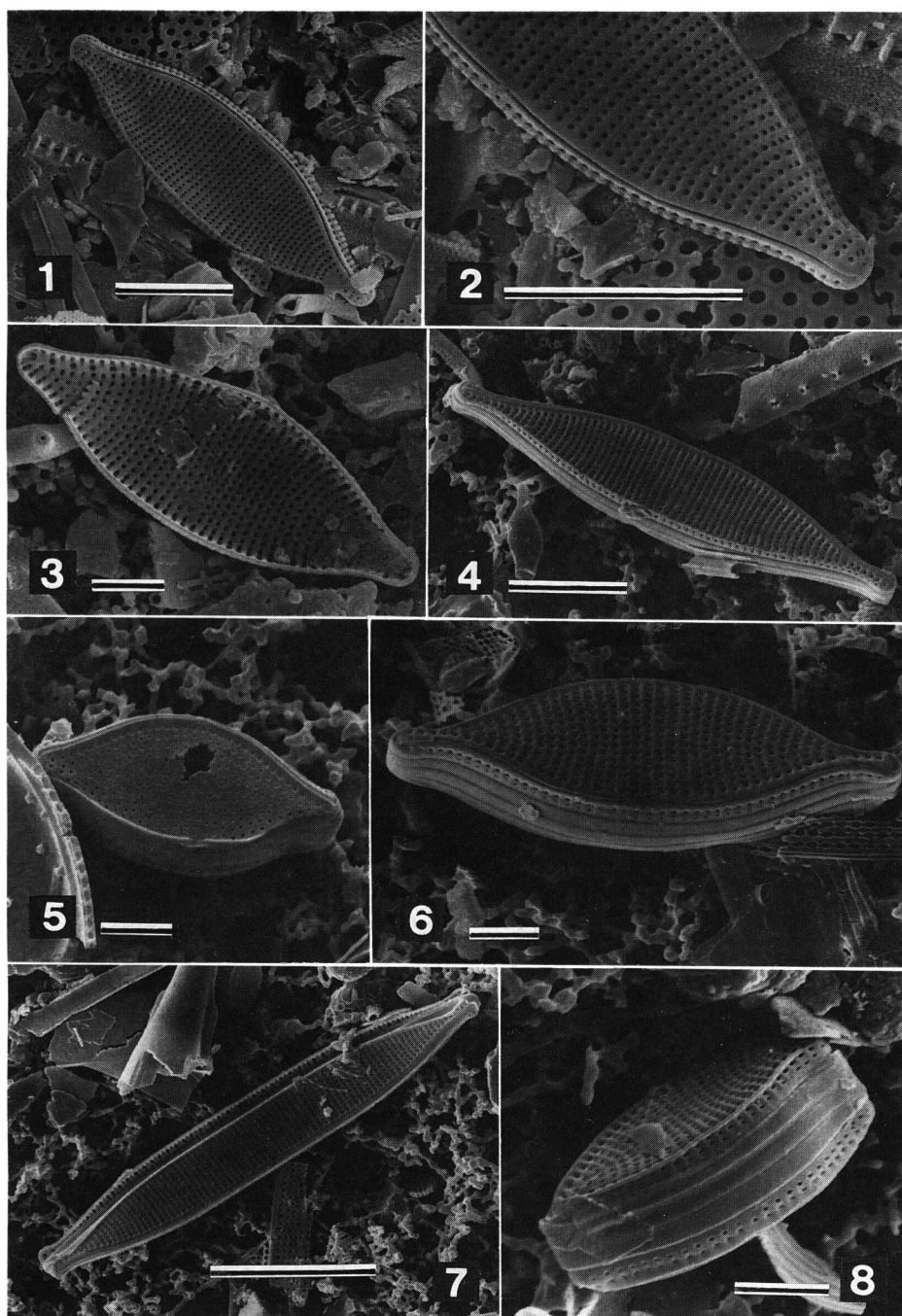
Synedra indica was originally described by TAYLOR (1966) from the South Western Indian Ocean and subsequently reported from several regions (e. g. the Indian Ocean, SIMONSEN, 1974; off Java Island, YANAGISAWA, 1987).

Examination of the trapped material by both scanning electron microscopy and light microscopy revealed that *Synedra indica* has characteristics which conform to those of the genus *Neodelphineis* described by TAKANO (1982, p. 45): Frustules in girdle view are rectangular with rounded corners. Length of perivalvar axis is 2–3 μm . Frustules are united into zigzag colonies. Valves are linear in larger specimens, having parallel or weakly three-waved margins and rounded ends, and are elliptical in smaller ones, 4–52 μm long, 2–3.5 μm wide. Valve face is flat except for an apical flat field obliquely crossing the valvar plane (Figs. 13–5 and –9). Transverse striae are formed of circular or elliptical areolae, 18–23 in 10 μm , slightly radiate, and interrupted by the narrow axial area. Areolae closed by rotulae having two supports. A single row of areolae is present on the valve mantle (Figs. 13–1 and –3). Short spines (Figs. 13–8 and –9) or elongated papillae (Figs. 13–1 and –3) form a line on the edge of the valves. At each apex, there is one small pore located in the narrow axial area (Figs. 13–1, –6 and –7), and a single rimoportula; the two rimoportulae at both apices are diagonally placed with respect to the axial area (Figs. 13–1, –6 and –7). The external rimoportula opening is a simple pore (Fig. 13–5), and the internal process is circular (Fig. 13–6).

Neodelphineis indica closely resembles *N. pelagica* TAKANO (1982, p. 40, figs. 1–34) in valve view under a LM observation. Both finely structured transverse striae and the presence of the apical flat field of *N. indica* (Fig. 13–5 and –9), however, are easily discernible diagnostic characteristics under a SEM observation.

Due to the weak silicification, *N. indica* (*S. indica*) is rarely found in sediments. This scant distribution in sediments make it difficult to know the distribution of the species. The available data, however, suggest a pelagic, rather than neritic, preference, while *N. pelagica* has been found in several estuaries of Japan (TAKANO, 1982).

Fig. 11. 1–8, *Nitzschia bicapitata* CLEVE emend. KACZMARSKA et FRYXELL; 1 and 2 outside view, detail showing raphe system, JT-01-1, scale bar=5 μm ; 3, inside view, whole valve showing slender fibulae, JT-01-1, scale bar=2 μm ; 4, JT-03-4, scale bar=5 μm ; 5, JT-03-4, scale bar=2 μm ; 6, outside view, frustule showing raphe system, JT-03-4, scale bar=2 μm ; 7, JT-03-4, scale bar=10 μm ; 8, outside view, frustule showing marginal ridge and girdle band, JT-03-4, scale bar=2 μm .



(Figs. 9–16~21, Figs. 13–1~9)

Nitzschia bicapitata–*N. bifurcata* complex

Nitzschia bicapitata CLEVE emend. KACZMARSKA et FRYXELL, 1984, p. 238, figs. 4–7, 9, 10; HASLE, 1964, p. 37, pl. 5, fig. 7, pl. 15, figs. 3–6; HASLE, 1976, p. 328, fig. 33.

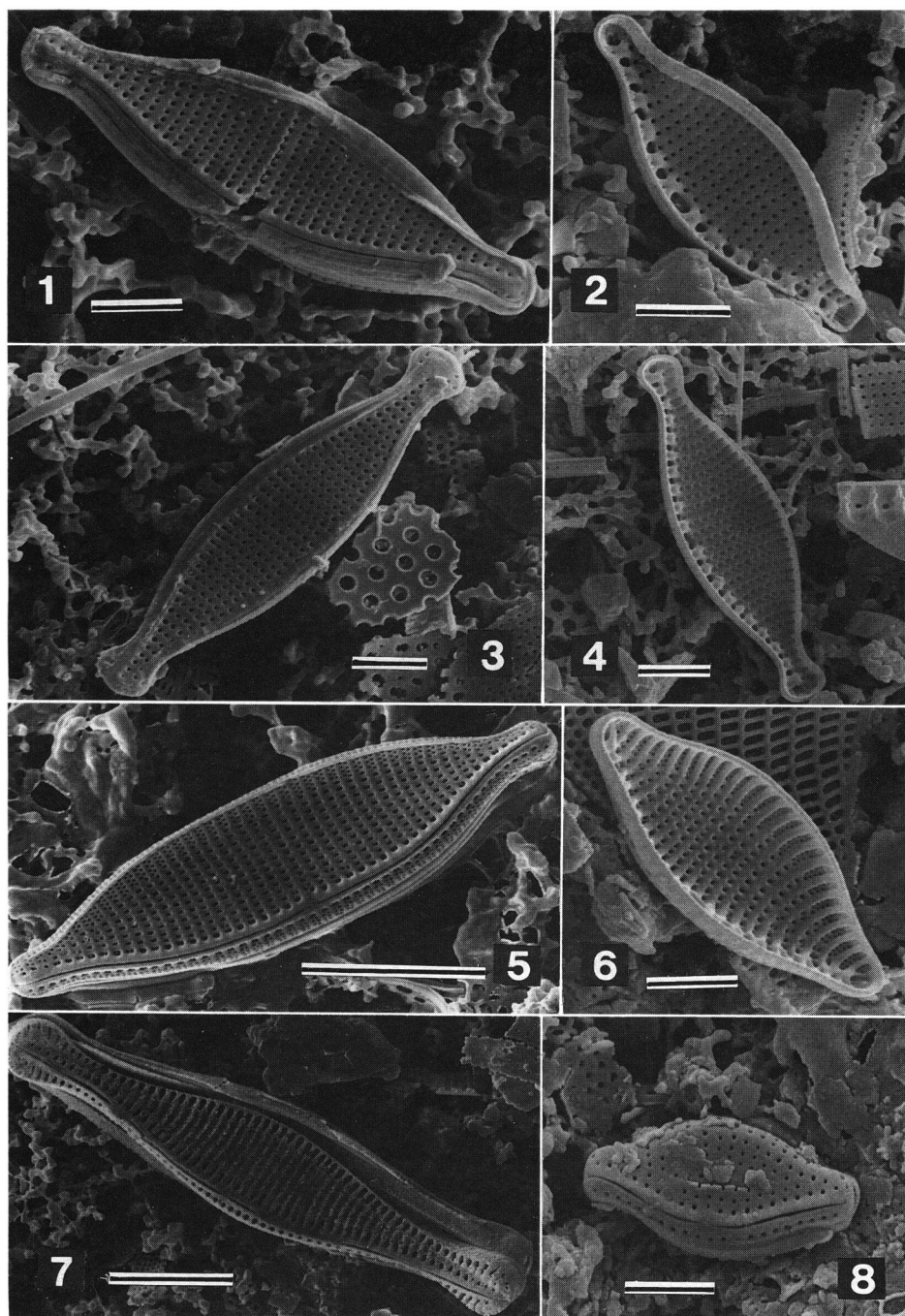
Nitzschia bifurcata KACZMARSKA et LICEA in KACZMARSKA and FRYXELL, 1984, p. 241, figs. 1–3, 8.

KACZMARSKA and FRYXELL (1984) have found two species being within the morphologic variation of small bicapitate *Nitzschia* species described as *Nitzschia bicapitata* CLEVE in a net flora from two Gulf Stream Warm Core Rings; *Nitzschia bicapitata* and their new species *Nitzschia bifurcata*. They stated that the differentiating characters between *N. bicapitata* and *N. bifurcata* are shape of foramina, near-margin structure of striae, number of striae and fibulae in 10 μm , width of valves, and shape of valves. Some of these morphological characteristics, number of striae in 10 μm , near-margin structure of striae (marginal transapical grooves in *N. bifurcata*), are not detectable in smaller specimens with LM. In addition, these two species are highly variable in morphology (e.g. HUSTEDT, 1958; SIMONSEN, 1974; HASLE, 1976; KACZMARSKA and FRYXELL, 1984), and hence more detailed observation will be necessary to obtain conclusive taxonomical information about these species and their relationship to their allied forms. I bundled thus these two species as “*Nitzschia bicapitata*–*Nitzschia bifurcata* complex” in counts of both relative species abundance and absolute diatom flux.

As mentioned above, “*Nitzschia bicapitata*” sensu lato is highly variable taxon. In the present material the wide variation of valve morphology is also observed: Valve outlines show great variability; elliptical-lanceolate, slightly capitate poles (Figs. 9–1 and –2, Figs. 11–5 and –8, Figs. 12–8 (?)); fusiform, slightly capitate ends (Figs. 9–11 and –12, Figs. 11–1, –2, –3 and –6); lanceolate, distinctly capitated poles (Figs. 9–4 and –5, Figs. 12–1~4); linear-lanceolate, gradually tapering towards both apices, terminating slightly capitate ends (Fig. 9–7); linear, linear-elliptical, parallel margins or slight constriction in mid valve, capitate poles (Fig. 9–6, Fig. 11–7); these were observed to range from 4.5 to 60 μm in length, and from 2.5 to 6.5 μm in width. Intermediate forms among them also occurred in the trapped material.

Striae are uniseriate, slightly arched, containing small and well separated areolae,

Fig. 12. 1–4, *Nitzschia bicapitata* CLEVE emend. KACZMARSKA et FRYXELL; 1, JT-03–4, scale bar = 2 μm ; 2, inside view, whole valve showing massive fibulae, JT-01–1, scale bar = 2 μm ; 3, JT-03–4, scale bar = 2 μm ; 4, inside view, whole valve showing massive fibulae, JT-01–1, scale bar = 2 μm . 5 and 6, *Nitzschia bifurcata* KACZMARSKA et LICEA; 5, outside view, frustule showing marginal small pores and raphe system, JT-03–4, scale bar = 5 μm ; 6, inside view, whole valve showing marginal grooves, JT-01–9, scale bar = 2 μm . 7, *Nitzschia capuluspalae* SIMONSEN, JT-03–4, scale bar = 5 μm . 8, *Nitzschia bicapitata* (?) CLEVE emend. KACZMARSKA et FRYXELL, outside view, whole valve without marginal ridge, JT-01–1, scale bar = 2 μm .



round or rectangular with rounded corners in outline, 26–34 in 10 μm . Raphe system is strongly eccentric in shorter specimens, and nearly straight in longer specimens. Marginal ridge is usually present on the opposite side of the raphe-bearing valve margin. Fibulae are massive in distinctive capitate specimens (Figs. 12–2 and –4), and are slender, like an English letter X, in fusiform specimens (Figs. 11–3 and –7). A single row or several rows of pores (Figs. 11–4, –6 and –8) are present on the mantle of the raphe-bearing valve margin. Girdle bands vary from 2 to 3 in number. (Figs. 9–1~7 and –11~14, Figs. 11–1~8, Figs. 12–1~4, and –8 (?))

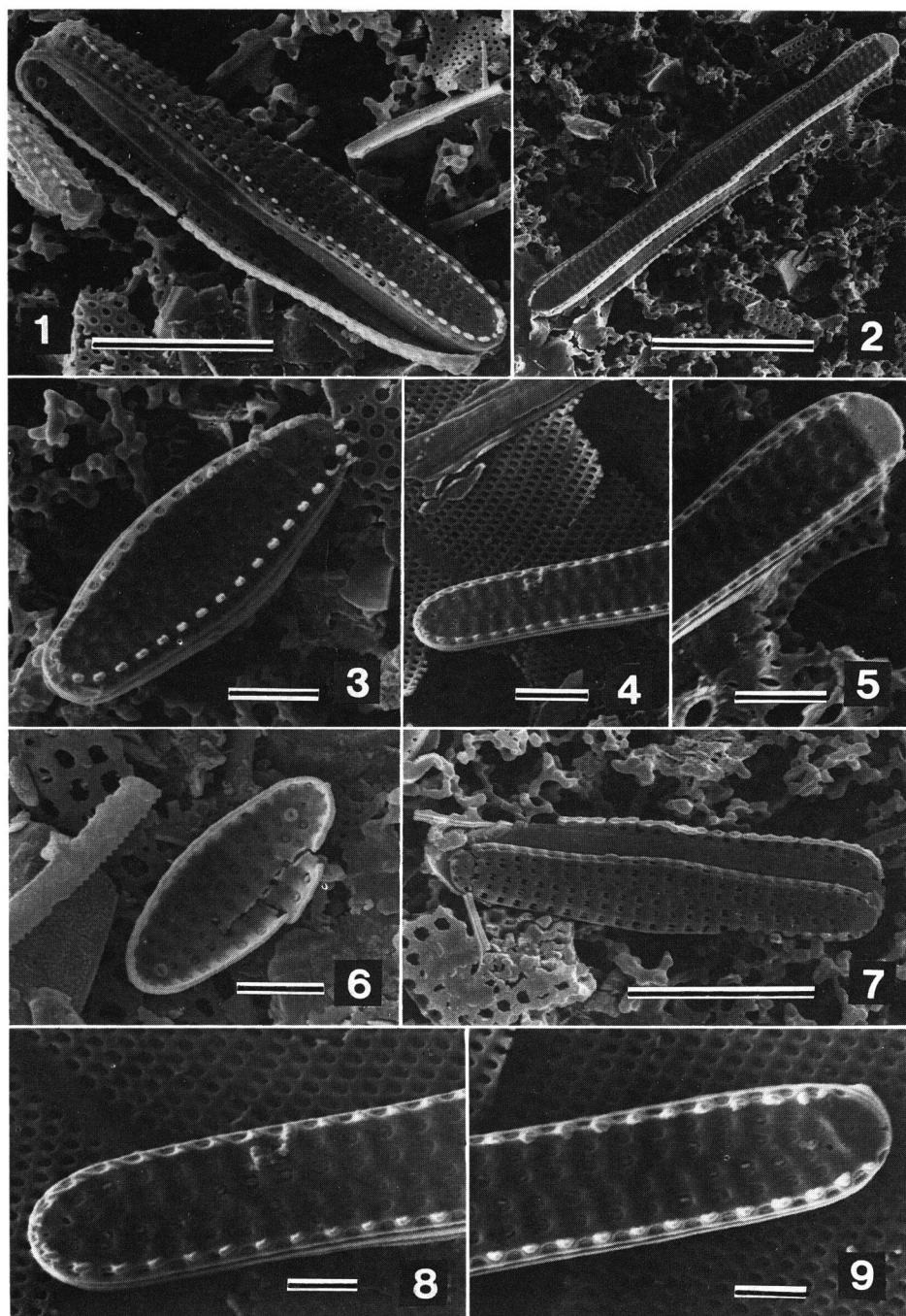
Valves of *Nitzschia bifurcata* vary in valve morphology less than do those of *N. bicapitata* (KACZMARSKA and FRYXELL, 1984). Observed specimens are slightly capitate fusiform (Figs. 9–8~10, Fig. 12–6) or capitate lanceolate (Fig. 12–5), and vary from 6.5 to 20 μm in length and from 4 to 6.5 μm in width. Transapical striae, 28–32 in 10 μm , are formed of a single row of areolae in most part of valve, and consist of two rows of small pores at the valve margin opposite the raphe (Fig. 12–5), and the same two rows of pores extends onto the mantle (Figs. 12–5 and –6). These pores have elongate external and nearly circular internal openings. Both raphe system and fibulae of *N. bifurcata* are similar to those of fusiform *N. bicapitata*. A series of internal transapical marginal grooves are present in *N. bifurcata* valves (Fig. 12–6). (Figs. 9–8~10, Figs. 12–5 and –6)

Nitzschia bicapitata sensu lato has been reported most area of the World Ocean, and appears to be almost cosmopolitan (Hasle, 1976), and the distribution of *N. bifurcata* probably corresponds to that of *N. bicapitata*. The fact that almost all “morphotypes” found in the present material were found only in a single fecal pellet supports this inference. All “morphotypes” of both *N. bicapitata* and *N. bifurcata* hence seem to share their habitat.

Thalassionema nitzschioides GRUNOW; HUSTEDT, 1932, p. 244, fig. 725; CUPP, 1943, p. 182, fig. 133; HASLE, 1960, p. 18; HASLE and MENDIOLA, 1963, p. 111, figs. 5, 11–17, 27–34, 39–44.

This heavily silicified and coarsely structured taxon was observed to range from 12 to 60 μm in length, and from 2.5 to 3.5 μm in width. This species is fairly variable in valve outline; larger specimens are more or less slender with narrow rounded ends, while smaller specimens have two parallel sides and bluntly rounded poles. On valve margins, cavities with internal pores form a line, 9–10 in 10 μm . (Figs. 8–5, –6 (?) and –7)

Fig. 13. 1–9, *Neodelphineis indica* (TAYLOR) TANIMURA, nov. comb.; 1, JT-03–4, scale bar = 5 μm ; 2, JT-03–4, scale bar = 10 μm ; 3, JT-03–4, scale bar = 2 μm ; 4, detail showing apical area without an apical flat field, JT-01–1, scale bar = 2 μm ; 5, detail showing an apical flat field, JT-03–4, scale bar = 2 μm ; 6, inside view, whole valve showing one small pore, and a single rimoportula at each apex, JT-03–4, scale bar = 2 μm ; 7, JT-01–1, scale bar = 5 μm ; 8 and 9, detail showing apical area with (9) and without (8) an apical flat field, JT-01–1, scale bar = 1 μm .



Appendix 1. Information on sediment trap moorings.

	Location	Water depth (m)	Trap depth (m)	Sample No.	Deployment dates	Duration (days)
JT-01	34°11.2'N 141°58.7'E	9,200	8,800	1	30 Aug. 1986–18 Sep. 1986	20
				2	9 Sep. 1986– 7 Oct. 1986	19
				3	8 Oct. 1986–26 Oct. 1986	19
				4	27 Oct. 1986–14 Nov. 1986	19
				5	15 Nov. 1986– 3 Dec. 1986	19
				6	4 Dec. 1986–22 Dec. 1986	19
				7	23 Dec. 1986– 1 Jan. 1987	19
				8	11 Jan. 1987–29 Jan. 1987	19
				9	30 Jan. 1987–17 Feb. 1987	19
				10	18 Feb. 1987– 8 Mar. 1987	19
				11	9 Mar. 1987–27 Mar. 1987	19
				12	28 Mar. 1987–15 Apr. 1987	19
				13	16 Apr. 1987– 4 May 1987	19
JT-02*	34°10.1'N 141°57.7'E	9,910	9,000	1	10 Jun. 1987–30 Jun. 1987	21
				2	1 Jul. 1987–20 Jul. 1987	20
				3	21 Jul. 1987– 9 Aug. 1987	20
				4	10 Aug. 1987–29 Aug. 1987	20
				5	30 Aug. 1987–18 Sep. 1987	20
				6	19 Sep. 1987– 8 Oct. 1987	20
				7	9 Oct. 1987–28 Oct. 1987	20
				8	29 Oct. 1987–17 Nov. 1987	20
				9	18 Nov. 1987– 7 Dec. 1987	20
				10	8 Dec. 1987–27 Dec. 1987	20
				11	28 Dec. 1987–16 Jan. 1988	20
				12	17 Jan. 1988– 5 Feb. 1988	20
				13	6 Feb. 1988–25 Feb. 1988	20
JT-03	34°11.34'N 141°59.53'E	8,951	4,000	1	15 Mar. 1988– 2 Apr. 1988	19
				2	3 Apr. 1988–20 Apr. 1988	18
				3	21 Apr. 1988– 8 May 1988	18
				4	9 May 1988–26 May 1988	18
				5	27 May 1988–13 Jun. 1988	18
				6	14 Jun. 1988– 1 Jul. 1988	18
				7	2 Jul. 1988–19 Jul. 1988	18
				8	20 Jul. 1988– 6 Aug. 1988	18
				9	7 Aug. 1988–24 Aug. 1988	18
				10	25 Aug. 1988–11 Sep. 1988	18
				11	12 Sep. 1988–29 Sep. 1988	18
				12	30 Sep. 1988–17 Oct. 1988	18
				13	18 Oct. 1988– 4 Nov. 1988	18

* Two automated sediment traps were placed on a mooring line at depths of 4000 m and 9000 m. No trapped materials, however, were collected with five cups of the shallower trap, owing to a trouble of the time-series collector.

Thalassionema nitzschioides var. *parva* HEIDEN in HEIDEN and KOLBE, 1928, p. 564, pl. 5, fig. 11; HASLE, 1970, p. 18, fig. 5 a.

Valves of *Thalassionema nitzschioides* and a series of its "varieties", var. *obtusum* GRUNOW, var. *lanceolata* GRUNOW, var. *javanica* HEIDEN, var. *inflata* HEIDEN, var. *incurvata* HEIDEN and var. *parva*, are variable in valve outline (HEIDEN and KOLBE, 1928; HASLE, 1960), and intermediate forms among them are apparently present. As HASLE (1960) pointed out, however, transitions between *T. nitzschioides* var. *parva* and others are rare. Observed specimens are 12–20 μm long, 4–5 μm wide, and have 9–10 marginal cavities and pores in 10 μm . (Fig. 8–4)

Acknowledgments

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Appendix 2. Diatoms found

SAMPLES/ DIATOM TAXA	JT-01, 8800 (m)																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	1	2	3	4	
<i>Achnanthes</i> spp.	1			3					1					1	1	2		
<i>Actinocyclus alienus</i>						3												
<i>A. curvatulus</i>		2		1	3		3		1		1		2		1			
<i>A. ingens*</i>									1									
<i>A. octonarius</i>		1			1	1	1	1	1			1	2			3	2	
<i>A. spp.</i>					1		1							1				
<i>Actinoptychus adriaticus</i> vars.				1	1												1	
<i>A. senarius</i>	1	2	2	5	3	5	1	1		2	3	2	5	1	1		2	
<i>A. splendens</i>																		
<i>A. spp.</i>	1										1			1				
<i>Amphora</i> sp. a	1							1	1				1		1			
<i>A. spp.</i>		1							2	1						1		
<i>Asterolampra marylandica</i>		2								2								
<i>A. spp</i>																		
<i>Asteromphalus arachne</i>									1					1			2	
<i>A. heptactis</i>	1		2	1						1								
<i>A. hookeri</i>	3					1				2		1		1				
<i>A. sarcophagus</i>															1		1	
<i>A. spp.</i>						2							2	1			1	
<i>Aulacosira</i> spp.																		
<i>Azpeitia africana</i>	1			4						1	2			1		1	1	
<i>A. nodulifer</i>						2								1				
<i>A. tabularis</i>	1	1	1	2		1		2	2	1	1		3	1	1	2	1	
<i>Bacillaria paxillifer</i>	1	1	1			1						1	3		2			
<i>Bacteriastrum comosum</i>	1		1				1	2			1							
<i>B. delicatulum</i>	1	1	1	2	1			2		1	2	1	4		5		2	
<i>B. elongatum</i>		2	3		3	1	1					2	1	2	2	2	2	
<i>B. hyalinum</i>	1	1	5	1		3	1	4	3	1				1	1	1	2	
<i>B. varians</i>	1	1	1		1	1	1			1					1			
<i>B. spp.</i>			2	1	3	3	1	1	4	4	2	4	2					
<i>Bacteriosira fragilis</i>																		
<i>Chaetoceros affine</i>		1	3	2	3		5	3	3	1		2	2		1		4	
<i>C. atranticum</i> var.																		
<i>neapolitana</i>	1		3	1				3	1	4	4	5	4	2	2			
<i>C. coarctatum</i>																		
<i>C. danicum</i>			1				1		1	1				1	1			
<i>C. decipiens</i>	3	5	2	3	1	2	4	3	10	9	10	9	4	12	9	10	12	
<i>C. denticulata</i>	1	4			2	1		3						3	6			
<i>C. didymum</i> +																		
<i>C. didymum</i> vars.	4	3		8	7	8	2	12	2	9	5	4	2		2	1	1	

in each sediment trap cup sample.

JT-02, 9000 (m)													JT-03, 4000 (m)												
5	6	7	8	9	10	11	12	13	1	2	3	4	5	6	7	8	9	10	11	12	13				
1													1												
2		1	2	1	2			3		1	2	1		4	4	5	2	2	2	2					
3				1		3		3	1	1	3 2 1 1														
1													1												
1	3	6		3	1		3	3	1	4	2	2	1	1	1	3	1	2	4	1					
2		1			1		2		4	2		1				1		1		2					
1		1		1		1		1		1		1		1		1		1		1					
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Appendix 2.

SAMPLES/ DIATOM TAXA		JT-01, 8800 (m)																	
		1	2	3	4	5	6	7	8	9	10	11	12	13	1	2	3	4	
C.	<i>lacinosum</i>				5	6	2	7	5	4	4	1	3			2	4	1	2
C.	<i>lorenzianum</i>	3	11	4	9	19	14	18	7	11	1	6	4	3		9	15	7	4
C.	<i>messanense</i>	2	7	6	11	7	6	8	9	5	2	5	9	5		7	3	10	6
C.	<i>peruvianum</i>			2			4	1	2		2		1						
C.	<i>pseudo-curvisetum</i>	4	5	17	10	4	3	10	6		1	2	4	13		8	9	5	6
C.	<i>radicans</i>	2	1	1	7	1	6	3	2	6	6	3	7	1		5	3	2	6
C.	<i>sociale</i>	1	1	3	2	4	2	1	6	5	3	4		1		2	4	7	3
C.	sp. a			3	2				2	2	6								4
C.	spp.	7	4	4	7	12	3	7	15	6	2	6	10	11		4	7	5	7
<i>Cocconeis costata</i>					1	1							1				1		
C.	<i>scutellum</i>					1		6	1			2	1		1			1	1
C.	spp.	2			4		3						2	1					
<i>Corethron</i> spp.							1	1											
<i>Coscinodiscus</i>																			
	<i>marginatus</i>															1		2	
C.	<i>oculusiridis</i>									1								1	
C.	<i>radiatus</i>																		
C.	<i>rothii</i>			1	1														
C.	<i>wailesii</i>						2												
C.	spp.	2	6	6	1	3	1			4	4	1	3					1	1
<i>Cyclotella striata</i>		1			3	2	3	1	1	1	1	2	3			1		3	4
C.	spp.								1						1		1		
<i>Cymbella</i> spp.												2							
	<i>Delphineis surirella</i>	1		1		2	1	3	2	1	2	2	3	1			2	1	4
<i>Denticulopsis hyalina</i> *												2							
D.	<i>katayamae</i> *																		
D.	<i>lauta</i> *													1					
<i>Detonula pumila</i>									1							2			
<i>Diploneis bombus</i>											1								
D.	<i>oculata</i>		1	2						2	3	1							2
D.	<i>weissflogii</i>	1									1								
D.	spp.					3				1	1							2	
<i>Ditylum brightwellii</i>			3	1			2		1							2	2	3	1
<i>Eucampia cornuta</i>			1			1													
E.	<i>zodiacus</i>	31	42	18	21	23	22	13	13	10	5	11	7	7		29	18	23	31
E.	sp.						1		1	3		1							
<i>Fragilaria</i> spp.					1		1	2			1	1							
<i>Grammatophora marina</i>													2						
G.	<i>oceanica</i>									1									
G.	spp.																		
<i>Gyrosigma</i> spp.			1		1			3	1	4				4					

Appendix 2.

SAMPLES/ DIATOM TAXA	JT-01, 8800 (m)																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	1	2	3	4			
<i>Haslea</i> spp.																				
<i>Hemiaulus sinensis</i>	11	2	4	1	3	2	4	2	5	2	8	5	4	4	3	6	5			
<i>H.</i> spp.			2		1						2		1							
<i>Hemidiscus</i> <i>cuneiformis</i>								1	1								1			
<i>Hyalodiscus scoticus</i>		1																		
<i>H.</i> spp.			1			1		1		1		2	1							
<i>Lauderia annulata</i>	5	3	2	4	4	3	4	1	2	5	4	3	5	1	2		3			
<i>L.</i> sp.	1				1			1						1	4	1	1			
<i>Melosira</i> sp.									1											
<i>Navicula</i> sp. a	3	1	1	2		2		1		1	4	5	2	3	4	2	4			
<i>N.</i> sp. b	5											2	2	2	1	3				
<i>N.</i> spp.	5	3	7	5	5	7	9	4	9	9	10	8	8	1	1	4	2			
<i>Neodelphineis indica</i>	43	44	41	38	36	23	39	53	40	35	43	20	53	42	52	31	50			
<i>N. pelagica</i>		3		4																
<i>Neodenticula</i> <i>kamtschatica*</i>																1				
<i>N. koizumii*</i>																				
<i>N. seminae</i>	4	2	4	4	2	4	3	3	5	1	4	4	4	3	3	7	2			
<i>Nitzschia bicapitata</i> – <i>N. bifurcata</i> complex	120	93	84	96	104	92	141	140	122	112	119	116	95	126	125	121	127			
<i>N. braarudii</i>	1	5		7	1		1	3	3			2	1		4	1	10			
<i>N. capuluspalae</i>					1	4	3	1						1	1	1	2			
<i>N. closterium</i>	1											10								
<i>N. constricta</i>	5	2	6	5	5	3	5	6	15	4	8	4	3	7	13	11	6			
<i>N. cruta</i>			1					1		2						1				
<i>N. cylindrus</i>								1					2			1				
<i>N. dietrichii</i>											1		3			3				
<i>N. grunowii</i>	1	1		1	1	3	5		1	3						3	1			
<i>N. inflatula</i> var. <i>capitata</i>	1	6		1	2				2	1	1	1		1	1	1	1			
<i>N. interruptestriata</i>	1	4	4	2	4	5	3		5	4			9	7	4	2				
<i>N. kolaczekii</i>	1		1						2					1	1					
<i>N. lineola</i>	3				4	1	2			2	1	9	4		3	1	1			
<i>N. marina</i>	3	4	4	3	4	1	2	4	4	3	3	2	3		2	2	4			
<i>N. pungens</i>	4	3	2	3	3	4	1	7	2	3	1	1	4	2	1	3	4			
<i>N. seriata</i> Group					2	2								1	1					
<i>N. sicula</i> + <i>N. sicula</i> vars.	2	5	9	8	8	10	4	4	2	4	1	2	7	2	3	4	2			
<i>N.</i> sp. a	2	2	2	2	1	1					1		1	1	1					
<i>N.</i> sp. b					4															
<i>N.</i> sp. c	3	1	2	1	1	2	1	2	6								2			
<i>N.</i> spp.	24	39	30	31	31	33	31	28	42	38	35	36	38	21	27	27	24			

Continued

JT-02, 9000 (m)													JT-03, 4000 (m)												
5	6	7	8	9	10	11	12	13	1	2	3	4	5	6	7	8	9	10	11	12	13				
										2		2						1			1				
8	16	7	4	6	6	4	4	5		4			2	1	2	2	5	1	3	7	3				
				2			2	1							1		1				1				
2	4	1	1	1			2	1			3	1					2	1	1	1					
	3										1	2	2	4	2		1								
		1	2																						
11	5	3	2		8	8	1		2	1	7	2	3	1	1				2	2	1				
	4	1						1	1	1	2		1	2	4	1	3				1				
1	1	1	5	2	2	1	1	3	6	3	5	2	1	6		3	3	2	1	5	3				
54	34	57	55	30	41	39	56	61	83	82	114	116	112	101	101	77	94	80	78	80	93				
	2	1	3				4									2			2						
			1														1				1				
							1																		
2	2	6	7	10	4	2	1	2	1		1		2	1	5	2	3	2	2	1	1				
140	126	103	91	92	91	86	98	111	177	181	129	134	126	145	124	127	135	159	139	148	141				
4	4	1	1		1	9	4	7	1	5		5	3	1		1		3	1	1	3				
2	2	1	3	2	5			2	1	1								1			2				
2	10	8	4	4	3	1	4	8	11	4	5	2	6	2	7	3	1	3	5	2	5				
																			1	1					
		1					1		1	1		1		1	1		2		1						
	3	2	3	3	6				1		3	1			1	1		1	1	1	1				
	3	1	1	4			4	2									1	1			2				
	1	1	1		2		1		2				1		1	1		1							
5	4	2		1	7	5	2	4	5	3	2	2	5	3	6	3	1	11	6	12	3				
		1															1				1				
	1		1				1		1				1			6	1	1		3	1				
1	2	2	9	6	2	3	5	3	3	1	1	1	4		2	2	1	4	2	3	2				
2	3	2	2	3	2	1	2	1		3	3	2	4	1	4	3	3	3	3	2	2				
4	3	1	6	3	7	3	9	9	4		3	4	3	1	4	5	1	2	7	5	5				
1		2						1							1	2			1		1				
						1			2	3	1				2	2		1							
					2						2				2										
22	18	17	24	27	20	13	30	26	31	24	35	42	32	33	27	16	29	34	36	28	27				

Appendix 2.

SAMPLES/ DIATOM TAXA	JT-01, 8800 (m)																
	1	2	3	4	5	6	7	8	9	10	11	12	13	1	2	3	4
<i>Odontella aurita</i>			4			6	3		2			5			2		1
<i>O. longicuris</i>		2	2	3	2		1	1	3	2				3		1	
<i>O. spp.</i>		2	1					3	2	2		2	1		1	2	
<i>Paralia sulcata</i>	2	2	10		1	2	3	3		2	2		2	2	5	1	1
<i>Planktoniella sol</i>	2	3	5	1	3	1	2									3	1
<i>Pleurosigma spp.</i>	3		3	1	2					2	2				2		
<i>Porosira sp.</i>		5	3	3					1			1					1
<i>Proboscia alata</i>			2		1		1	1						1			
<i>Pseudoeunotia doliolus</i>	6	6	2	2	4	2	2	6	4	2	1	5	3	7	4	3	5
<i>Rhizosolenia bergonii</i>	4	4	5	2	4	5	3		2	6	3	4	2		1	2	1
<i>R. calcar-avis</i>	3	1	1	1	3	2	3	1	2	1	1	2	1	3	3		
<i>R. hebetata</i>	3	4	1	3	8	3	4	1		4		1	4		2	3	3
<i>R. imbricata</i> var. <i>shrubslei</i>	4		8	7		3	6	4	2	2	3	5	2	4	1	3	3
<i>R. setigera</i>	5	2	7	2	4	4	6	5	8	9	9	5	3	1	2	9	4
<i>R. styliiformis</i>		2	1	2			1	1	1	1			1	1	2		
<i>R. spp.</i>									1			1	1				
<i>Roperia tessellata</i>	2		2	5	1			1	2	4	1	2	1	7	2	1	2
<i>Skeletonema costatum</i>	8	1	5	5	9	7	1	7	10	1	4	2	2	1	6	16	4
<i>Stellarima spp.</i>		1			1	1		2		2							
<i>Stephanopyxis spp.</i>		2	1	2		1					1						
<i>Synedra spp.</i>						2	1									2	
<i>Thalassionema bacillaris</i>	10	12	16	16	12	12	14	14	11	9	11	12	23	15	11	15	14
<i>T. nitzschioides</i>	51	50	60	49	44	45	56	30	33	41	35	44	46	30	20	31	33
<i>T. nitzschioides</i> var. <i>parva</i>	25	14	19	16	32	17	9	17	15	25	19	20	18	34	28	18	19
<i>T. spp.</i>	1		1	1	2						1	2	7		1		3
<i>Thalassiosira angustelineata</i>	3	2		1	2	3		2	3	5	1					4	
<i>T. decipiens</i>	2	1	2	4		3	2			2		2	1	4		2	
<i>T. eccentrica</i> + <i>T. eccentrica</i> vars.	2	1	1	1	1	3	3		1			2	1	2			1
<i>T. gravida</i>														1			
<i>T. hyalina</i>					1	1									2		
<i>T. kryophila</i>													1				
<i>T. leptopus</i>		2		1						1	2	4	1				
<i>T. lineata</i>	4	9	7	11	9	7	9	7	11	3	4	5	3	9	3	6	8
<i>T. nordenskiöldii</i>					1	1	2	1	3	2	2	1	3	1	3	1	
<i>T. oestrupii</i>	9	13	7	14	11	9	7	9	7	7	6	10	12	12	14	9	9
<i>T. pacifica</i>			1					1				1					
<i>T. subtilis-diprocyclus</i>																	
Group	2			4	1	1	4			1		1		1	3	4	

Continued

JT-02, 9000 (m)										JT-03, 4000 (m)													
5	6	7	8	9	10	11	12	13		1	2	3	4	5	6	7	8	9	10	11	12	13	
2	3	3	2	6	3	6	1	5	5					2	2	1	2	2	4	1	2	2	
1	1	1	4	2	2	2	2	1			1		1	1	1	1						3	
										1						1				1			
3	3	5		6	1	6	4		2		1	1	1	1	1		1	2	1			1	
	9	3	3	2		1	8	10		1	1					1		1	2				
1	2	1		1		1	1	2		3	3	1	1			1	1	1		2			
1	1			4		6	3	1													1		
1	1			1		1		2					1			1		1	1	1			
2	4	4	6	10	4	4	4	5	3	4	7	11	5	6	1	5	12	7	4	6	3		
1	3	3	4	6	2	3	4	4	4	2	1		3	1	1	2	1			2	2		
2	2	3	2						3										1	1			
1	4	3	4	4	6	5	3	5		2	3		2	3		4	2	2	3	1	3		
3	3	3	1	6	4	1	2			2	2	1	4	7	2	8	3			2			
2	7	4	13	9	7	12	9	5	2	4	3	8	2	9	5	1	4	8	4	6	3		
1	2	2	3	2	3			1		1	1		1				1		1	2			
		1		1	1			2	1				1		1				1				
	2	2	3	1	2	4	1	2	2	2	3		1	2	1		2	5	2	1	1		
	3	2	7	7	2	3	3	4				3			2				4	2	1		
					2		3		2	1									1	1	2		
						1				2				2					1				
																			1				
14	17	25	15	24	16	21	20	25	15	17	5	8	7	13	20	22	19	19	17	14	23		
36	35	45	28	52	47	69	48	52	31	25	11	29	54	43	50	43	47	37	42	46	41		
33	21	33	30	24	35	34	34	12	17	15	15	12	9	6	7	6	7	10	13	13	17		
		1							1		1												
5	1	3			1	3	4	6						1			1			1	6	3	
	1	5	2	1	3		4	1		1		1	1	5	1		4	1	1		4		
1				2	1			2		2	1	4				1		2	2	2	2		
						3					1					1		1					
	2	1	2	1	1		1	3		2		1	1	1	1	4	3	1	3	2		1	
			2							1	1							1					
		1	1					1															
7	7	11	5	4	8	10	11	3	3	4	6	3	7	3	7	7	3	8	5	1	7		
1	2	3	2	2	1	2			1	1	1	2						1		1			
7	16	5	16	11	12	11	16	10	9	8	2	5	8	7	6	9	2	1	6	8	6		
						1																	
2	2		1				1	2	4		1			2	3	2			1	3			

Appendix 2.

SAMPLES/ DIATOM TAXA		JT-01, 8800 (m)																
		1	2	3	4	5	6	7	8	9	10	11	12	13	1	2	3	4
<i>T. symmetrica</i>					2		8				6	9		1	2		2	
<i>T. tenera</i>		6	1		3	1		3	1	1	2		1		2		1	2
<i>T. trifulta</i>			1	1		1	1	1		1	3			1	2		2	3
<i>T. sp. a</i>		2	5	1	6			3	1	7	8	20	12	7	2		4	
<i>T. sp. b</i>			6			1	2	1	1	1	3	1	1	1		2	2	2
<i>T. sp. c</i>			3	1	1			1	1	4	1			5	2	7	3	5
<i>T. spp.</i>		3	12	1		2	5	9	3	4	3	7	6	2	7	7	5	9
<i>Thalassiothrix</i>																		
<i>delicatula</i>				2	1							5		1	1	1	2	3
<i>T. frauenfeldii</i>		8	12	6	11	19	15	7	19	9	13	9	11	9	6	4	8	8
<i>T. longissima</i>		1	6	4	7	3	6	8	6	9	10	4	5	11	5	3	7	2
<i>T. mediterranea</i>		2	1	1	1		1	2	2		1	1			1	3	3	6
<i>T. pseudo-nitzschioides</i>		4			3	2	1	2	2	2		1	2	1			2	
<i>T. vanhoeffenii</i>		6			1	2	2	1	2	1			2		2	2	3	1
<i>T. spp.</i>		2		3	2	2	9		3	1	1	4	5	6			1	1
<i>Trachyneis aspera</i>																		
<i>Triceratium</i> sp.																		
<i>Trochosira spinosa</i>																		
Others																		
Total number of diatom valves counted																		

* fossil taxa

Continued

JT-02, 9000 (m)													JT-03, 4000 (m)												
5	6	7	8	9	10	11	12	13	1	2	3	4	5	6	7	8	9	10	11	12	13				
1		1	4	3		5	1					1							1						
2	1			7	2	3				2	3	4	3	3	3	1	2	1		3					
2	1		1	9	4	4		1		1	4	3	1	3	3	1	2	2	1	4					
		3	3		2	1			2	2	2	5			3		1								
	1	1	4			3	1	1	2		1	2			2			1	1		3				
1	6	5	2	2	7	4	5	8	5	9	12	17	10	10	5	10	5	2	2	1	2				
4	2	5	4	9	9	7	3	6	3	5	7	6	4	7	7	7	6	7	10	4	2				
6	9	7	17	11	9	14	6	7	8	10	3	5	2	2	2	5	3	9	7	5	8				
5	4	7	7		4	5	6	3	3	1			1	3	1	6	3	3	3	5	5				
2	4	3	7	5	7	6	3	3	3	1		2	3	3	1	3	7		1	4	3				
				6		1																			
1	2	1	2	3	2		3				1		1	1	2	1				2	2				
1	1						3			3				1	2	1			1	1					
													1												
16	14	15	14	5	10	18	23	7	17	11	25	18	10	6	13	13	11	18	11	10	16				
541	544	542	577	575	548	577	577	544	536	527	527	558	539	535	513	511	524	537	523	539	529				

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