# Environment at the Front Shore of the Institute of Algological Research of Hokkaido University*

By
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## Introduction

The Institute of Algological Research of Hokkaido University is in Muroran City (42° 19′ N ; 141° 50′ E) where is located at the northeastern part of the mouth of Uchiura-Wan (Volcano Bay), Hokkaido, Japan. Charatsunai shore, the front shore of the Institute, is mostly occupied by rocks. Many kinds of organisms including about 200 taxa of benthic algae richly grow there.

Staffs of the Institute and many visiting researchers investigate many algae growing there morphologically, physiologically and ecologically. Till now, two environmental factors in the shore, seawater temperature and specific gravity, have been recorded by the Institute. Besides those two factors, it has been expected to measure other environmental factors such as nutrients in seawater, pH of seawater, etc. for making clear the environment of this shore.

I studied autecologically a marine tube-dwelling diatom, *Berkeleya obtusa* (GREV.) GRUNOW, at Charatsunai shore in the doctor course of Hokkaido University. At that time, many environmental factors were measured at several points of the shore as the basical data for discussing the autecology of *B. obtusa*.

This paper reports some environmental factors of Charatsunai shore, and is a section of "Autecological studies on the marine tube-dwelling diatom *Berkeleya obtusa* (GREV.) GRUN."

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mental Science and Technology Center for their help with analytical technique and their encouragement.

# I Area surveyed and methods

## 1. Area surveyed

The wide rocky flat with a size of ca. 100 m×50 m juts out into the sea at the central part of Charatsunai shore. This flat is mostly 10–60 cm above the datum line, but has a large rock with a height of about 2 m at the middle portion of the flat. This flat emerges at low water. The other part of Charatsunai is the narrow, rugged shore consisting of rocks, shingles and pebbles and some rock pools are formed in this area at low water. At the east part of the shore, there is a small fall of fresh water.

The landward of the central flat and the rugged shore were decided as study areas. Temperature, pH and salinity of seawater were measured at one cleft and four pools in these areas (Figs. 1 and 2).

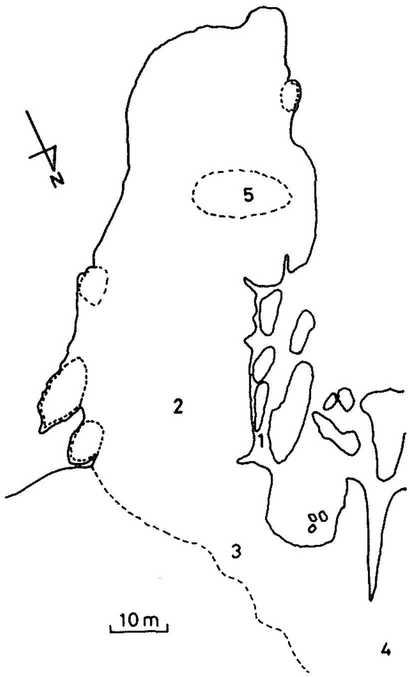


**Fig. 1** Map of the research points of physico-chemical analyses.
1, the Cleft-1; 2, the Pool-1; 3, the Pool-2; 4, the Pool-3; 5, the Pool-4.

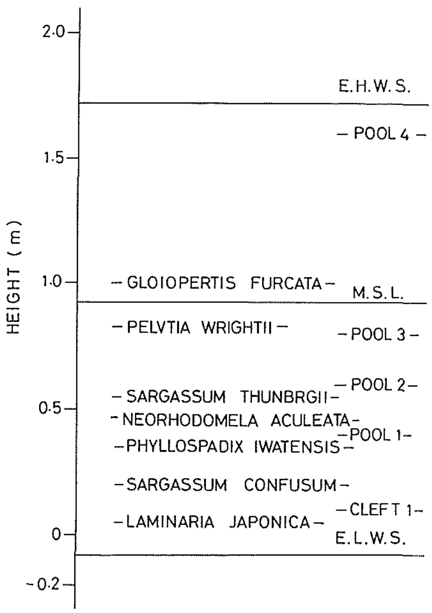


**Fig. 2** Vertical distribution of the cleft and pools at Charatsunai. E. H. W. S., extreme high water spring; M. S. L., mean sea level; E. L. W. S., extreme low water spring. Data were obtained from tide table (Japan Meteorological Agency 1977).

Cleft-1 (C-1) (Fig. 1-1) (10 cm above the datum line) was located at the north side of the central flat and many rocks emerging at low water were scattered in the cleft. The following plants grew abundantly there: *Alaria crassifolia* KJELLMAN, *Laminaria japonica* ARESCHOUG, *Sargassum confusum* C. AGARDH, *S. thunbergii* (MERTENS) O. KUNTZE, *Palmaria palmata* (LINNAEUS) STACKHOUSE, *Phyllospadix iwatensis* MAKINO, etc.

Pool-1 (P-1) (Fig. 1-2) (40 cm above the datum line) was located at the center of the landward of the central flat. *Neorhodomela aculeata* (PEREST.) MASUDA, *P. iwatensis*, etc. grew in this pool. This pool was 0.1 m deep and occupied an area of 1 m×1 m.

Pool-2 (P-2) (Fig. 1-3) (60 cm above the datum line) was located at a most landward part of the central flat. This pool was 0.15 m deep and occupied an area of 1.5 m×1 m. The bottom of the pool was sandy, but covered mostly with *N. aculeata.*

Pool-3 (P-3) (Fig. 1-4) (80 cm above the datum line) was a bare rock pool situated at the rugged shore. This pool was 0.1 m deep and occupied an area of 0.6 m×0.4 m.

Pool-4 (P-4) (Fig. 1-5) (160 cm above the datum line) was a shallow pool on the central large rock of the central flat. This pool was 0.1 m deep and occupied an area of 2 m×1.5 m. *S. thunbergii, Corallina pilulifera* POSTELS et RUPRECHT and sea mussels grew there.

Seawater samples for nutrient analyses were collected from the following five points (Fig. 3):

Point-A was in the front of the Institute of Algological Research.

Point-B was in the central flat.

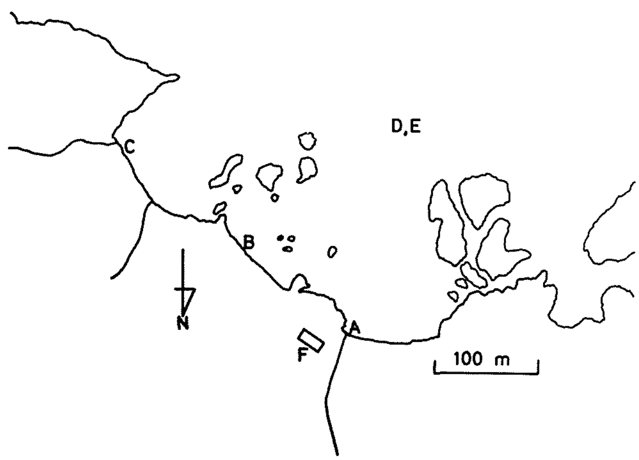


**Fig. 3** Map of sampling points for the analyses of nutrients.
A, the Point-A; B, the Point-B; C, the point-C; D, the Point-D; E, the Point-E; F, the Institute of Algological Research of Hokkaido University.

Point-C was near the small fall in the east part of the shore.

Point-D (surface) and E (bottom, depth of 10 m) were at about 200 m off the shore.

## 2. Measurements of temperature, pH, salinity, evaporation value of water, and nutrients

Air and seawater temperatures were measured by a mercury thermometer for 2 weeks per one month from April 1977 to April 1979. These measurements were carried out 4 times a day (10 : 00, 13 : 00, 16 : 00 and 20 : 00). Air temperature was measured at the open place near the Institute of Algological Research. Seawater temperature was measured *in situ*.

Value of pH was measured at the same frequency and period with the measurement times of temperature. Water sample was carried by 100 m*l* polyethylene bottle to the laboratory and the pH value was recorded using pH meter (Model HM-5B, Toa Electronics Ltd.).

Salinity was measured at the time of the lower low water of spring tide from February 1978 to April 1979. The measurement of salinity was made for 10 m*l* seawater (filtered by glass filter) by titration with silver-nitrate using uranine-starch as an indicator (Japan Meteorological Agency 1970).

Littoral benthic algae periodically emerge at low water. At that time, the organisms will be dehydrated. The vertical distribution of these algae is partially determined by their

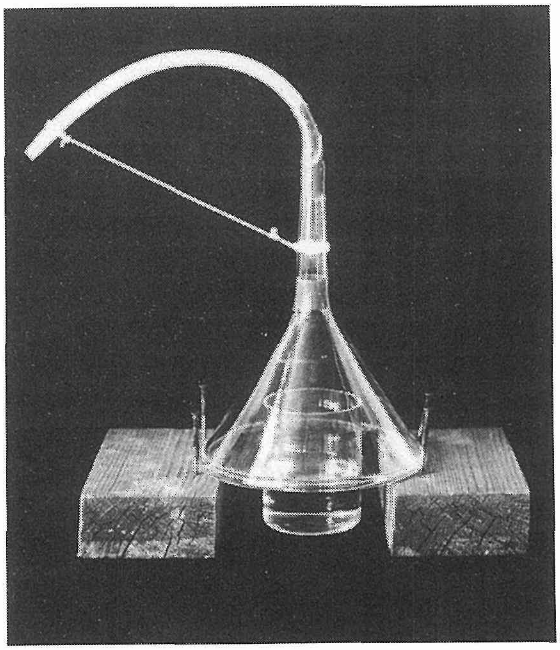

**Fig. 4** Measuring apparatus for evaporation of water. A beaker was 6 cm of diameter and 8.5 cm in depth.

resistivity to desiccation (BIEBL 1962, ZANEVELD 1969). The desiccation seems to be determined not only by humidity, but also by other atomospheric conditions such as temperature, wind, etc. So it is necessary to measure the evaporation value of water. In this study, the evaporation value of water was recorded from November 1977 to April 1979.

The evaporation value of water was measured by the following method: A tall beaker (6 cm diameter×8.5 cm depth) containing 100 g of distilled water (precooled at 14℃) was weighed and then it was set at the open place. The tall beaker was covered with a glass funnel (15 cm diameter) with a bent polyethylene tube at the tip (Fig. 4). After 2 or 3 hours, the beaker was weighed again and an evaporation value of water was calculated. The evaporation value was measured twice a day, the first setting was started at 10 o'clock in the morning and the second time was done just after sunset. The evaporation value was presented as the value in grams per basal area of test beaker (28 cm$^2$) per hour.

Ammonia-N, nitrite-N, nitrate-N, phosphate-P and silicate-Si of seawater were measured monthly from January 1976 to April 1979. The seawater samples were collected in 500 m*l* polyethylene bottles at 10 : 00. Analytical methods for subjective elements were as follows:

Ammonia-N

The indophenol-nitroprusside colorimetric method (ISHISAKA 1969) was used.

Nitrite-N

The sulfanilamide-N (naphtyl) ethylenediamine colorimetric method (Japan Meteorological Agency 1970) was used.

Nitrate-N

The seawater sample was reduced by copper-cadmium (Japan Meteorological Agency 1970). Then, the same method for nitrite-N was used.

Phosphate-P

The Menzel method (Japan Meteorological Agency 1970) was used.

Silicate-Si

The molybdate-amino naphthol sulfonic acid colorimetric method (Japan Society for Analytical Chemistry, Hokkaido Branch 1971) was used.

Analyses of ammonia-N, phosphate-P and silicate-Si were completed within the day of collection. The seawater sample for analyses of nitrite-N and nitrate-N was sometimes stored at −25℃.

All measurements for nutrient determinations were carried out in duplicate and the mean value of duplicate was present in the relevant figures.

## II Results

### 1. Air temperature

**Seasonal variation of air temperature at 13 : 00** (Table 1)

Among 4 measurement times a day, air temperature always reached to the highest value at 13 : 00. The monthly mean temperature was 12.5℃ in April 1977, the beginning of this investigation. Then, it gradually rose until September 1977, and was recorded the highest mean value of 22.1℃. In Octeber 1977, it was 20.3℃ and gradually decreased until February 1978 and the lowest mean value of −1.4℃ was recorded. In March 1978 it greatly rose to 8.4℃.

The monthly mean temperature of April 1978 was slightly higher than that of the preceding year. The seasonal variation of the monthly mean temperatures of the second cycle (Apr. 1978–Apr. 1979) showed almost similar pattern to that of the first cycle (Apr. 1977–Mar. 1978). In 1979, however, the lowest mean temperature of −1.6℃ occurred not in February but in January. Then the monthly mean temperature gradually increased from February to April in the second cycle. Furthermore, during the summer of the second cycle, it was higher than that of the first cycle.

**Seasonal variation of air temperature at other times** (Table 1)

The variation patterns of air temperature at other measurement times were just the same manner with the case of the measurement at 13 : 00. In these measurements, the lowest mean temperature of −5.9℃ in the first cycle was recorded at 20 : 00 of February 1978, and in the second cycle the lowest value of −3.8℃ occurred at 20 : 00 of January 1979.

## 2. Seawater temperature

**Seasonal variation of seawater temperature at the Cleft-1 at 13 : 00** (Tables 2 and 3)

The seawater temperature always reached the highest value at 13 : 00 among 4 measurement times a day. The monthly mean temperature was 6.5℃ in April 1977. Then, it gradually rose until September 1977, and reached to the highest value of 18.5℃. In October 1977 it slightly decreased to 16.8℃. Then it gradually decreased until February of the next year (1978), and the lowest value of 2.3℃ was recorded in Frbruary. In March 1978 the mean value slightly rose.

The monthly mean temperature of April in 1978 was the same level with that of the preceding year. The seasonal variation of the monthly mean temperature of the second cycle (Apr. 1978–Apr. 1979) showed almost similar pattern to that of the first cycle (Apr. 1977–Mar. 1978). However, the monthly mean temperatures of June and July 1978 were higher than those of the preceding year and the value of April 1979 was slightly lower than those of 1977 and 1978.

**Seasonal variation of seawater temperature at the Cleft-1 at other times** (Table 2)

The variation patterns of seawater temperature at each measurement time other than 13 : 00 were just the same manner with the case of 13 : 00. In these measurements, the lowest temperature of each year was recorded at 20 : 00 as 0.8℃ in February 1978 and 1.5℃ in March 1979.

**Seawater temperature at other points** (Table 3)

At the Pools 1–4 situated at higher levels than the Cleft–1, seawaters were out of contact with the open sea at the low water, as the result, shallow pools were formed there. At that time, the water temperatures of shallow pools of these points were affected by the air temperature. At Muroran, the lower low water of spring tide occurs in the nighttime from late September to early March, but during other months it occurs in the daytime. As shown in Table 3, the seawater temperatures of the Pools 1–4 were lower than that of the Cleft–1 in the nighttime from late autumn to winter and often dropped below freezing point. But the seawater temperatures at the Pools 1–4 were higher than that of the Cleft–1 during daytime from spring to early autumn. The temperature differences of more than 10℃ between Cleft –1 and Pools 1–4 were often observed during this period.

## 3. Tidal emersion

The littoral zone is defined as the range from the extreme high water of spring tide to the extreme low water of spring tide (NISHIHIRA 1976). At Muroran, it is ranging from +172 cm to −8 cm of the datum line (Japan Meteorological Agency 1977). LEWIS (1964) showed that the occurring time of the lower low water of spring tide changes with the season. At Muroran, the lower low water of spring tide occurs in the nighttime from late September to early March, and occurs in the daytime from late March to early September.

Usually spring tide occurs twice a month. The time and duration of emersion for 5 days at each spring tide were estimated using the tide tables (Japan Meteorological Agency 1976, 1977) and monthly fluctuations of them at five different levels in height were described below.

**Tidal emersion at the level of 10 cm above the datum line (Cleft–1) at spring tide** (Tab. 4)

This level emerged for less than 4 hours in the nighttime from November to February, and submerged in the nighttime during other months. In the daytime, this level emerged for less than 3 hours from April to July and submerged from August to March.

**Tidal emersion at the level of 40 cm above the datum line (Pool–1) at spring tide** (Tab. 5)

In the nighttime, this level usually emerged for 3–6 hours from October to March, but did not emerge from April to August. In September, this level emerged again for less than 3 hours in the nighttime. This level usually emerged for 3–6 hours in the daytime from March to July. The emersions of 1–4 hours and 0–2 hours occurred in the daytime of August and September, respectively. From October to February, this level submerged in the daytime.

**Tidal emersion at the level of 60 cm above the datum line (Pool–2) at spring tide** (Tab. 6)

In the nighttime, this level usually emerged for 4–8 hours from October to February, and emerged for 0–6 hours from March to September. In the daytime, this level emerged for less than 4 hours in February and usually for 4–7 hours from March to August. This level emerged for 2–5 hours and 0–3 hours in the daytime of September and October, respectively.

From November to January, this level did not emerge in the daytime.

**Tidal emersion at the level of 80 cm above the datum line (Pool-3) at spring tide** (Tab. 7)

In the nighttime, this level emerged for 5–9 hours from September to March. In September and March, however, the emersion of less than 5 hours was also observed. The emersion of 0–5 hours occurred in the nighttime from April to August. In the daytime, this level emerged for less than 4 hours from November to January, and the frequency and duration of the emersion in February were larger than those from November to January. In March, the long time emersion of more than 6 hours also occurred in the daytime. The emersion of 5–9 hours occurred in the daytime from April to August. The emersions of 4–6 hours and 3–4 hours frequently occurred in the daytime of September and October, respectively.

**Tidal emersion at the level of 160 cm above the datum line (Pool-4) at spring tide**

This level always emerged from February to April and in September, but submerged for less than 3 hours per day during other months.

## 4. pH of seawater (Tables 8 and 9)

The pH range of seawater at the Cleft-1 was usually 8.0–8.5 through the year. However, from October to April, the pH sometimes fell into 7.5–8.0 and from February to July it sometimes rose to 8.5–9.0. The Cleft-1 was in contact with the open sea even at the lower low water, but the seawater in the Cleft-1 became stagnant. Accordingly, as a result of photosynthesis and respiration of organisms living in the Cleft-1, the pH value fluctuated as did in a tide pool (ATKINS 1922, PYEFINCH 1943, ALEEM 1950, EDELSTEIN and MC-LACHLAN 1975).

From late September to early March, the lower low water of spring tide occurred in the nighttime, and the pH fell into less than 8.0 due to the respiration of organisms. On the other hand, from late March to early September, the lower low water of spring tide occurred in the daytime, and the pH rose to 9.0 due to the photosynthesis of plants.

This tendency was more clearly shown in the higher sampling points than the Cleft-1. Especially, at the Pool-4 the pH fell into 7.5 in the nighttime and rose to more than 9.0 in the daytime. It had a tendency that the extreme high pH was more frequently observed from late March to April, and at the Pools 1–2 it rose to more than 9.0 during this period.

It was demonstrated that pH of seawater at all sampling points usually fell off when *emersion occurred in the nighttime*, while, pH rose when *emersion occurred in the daytime*.

## 5. Salinity of seawater at the lower low water of spring tide (Table 10)

As a result of heavy rainfall, the lowest salinity of 14.15‰ was recorded at the Pool-4 on July 7, 1978. On the contrary, the highest one of 41.44‰ occurred at the Pool-4 on the cold day, January 11, 1979.

The Cleft-1 is usually in contact with the open sea even at the lower low water. Salinity at the Cleft-1 was in the range of 31–34‰ during measuring period except the cases of June 21, 1978 (14.24‰) and July 7, 1978 (24.12‰). The seasonal fluctuation of the salinity at the Cleft-1 was observed. In September, salinity rose to 33.46–33.67‰ and the level of 33‰ lasted into January. In February, it slightly fell to 32.43–32.99‰ and the range of 31–32‰ continued until August.

OHTANI *et al.* (1970, 1971a, 1971b) studied on the changing pattern of hydrographic conditions in Uchiura Bay and reported that the cold and low saline waters of the Oyashio Current intrude into the northeastern side (Muroran) of this bay through the upper layer from March to May, and these waters stay in the bay during summer. The warm and high saline waters of the Tsugaru Current reach the northeastern mouth of Uchiura Bay in June -July and enter the bay through the mid and lower layers from August to October and these waters stay in the bay during winter. The seawater in this study area may be influenced by the Oyashio and Tsugaru Currents.

Salinities at the Pools 1–4 were higher than those of the Cleft-1 during January and February. This phenomenon is due to the fact that low temperature in winter caused the high salinity as a result of freezing-out of salt during the formation of ice (EDELSTEIN and MCLACHLAN 1975).

## 6. Evaporation value of water (Table 11)

### In the daytime

Evaporation value was higher in a fine weather than in a cloudy or rainy weather, and higher value was observed in the condition of higher temperature. The highest monthly mean value of 0.88 g/28 $cm^2$/hr was observed in August 1978. The lowest value of 0.20 g/28 $cm^2$/hr was obtained in January 1978. This lowest value was the result of continuous decrease from the monthly mean value of 0.37 g/28 $cm^2$/hr in November 1977. In February 1978, it was 0.24 g/28 $cm^2$/hr and abruptly rose to 0.54 g/28 $cm^2$/hr in March 1978. From April to June 1978, lower evaporation values were recorded, especially in May, as compared with that of March. It was caused by the wet weather (claudy, rainy and foggy) held for these months. The monthly mean value rose to 0.66 g/28 $cm^2$/hr in July 1978, and the annual maximum value of 0.88 g/28 $cm^2$/hr was recorded in August 1978. Then, it gradually fell to 0.74 g/28 $cm^2$/hr in September 1978 and to 0.51 g/28 $cm^2$/hr in October 1978. The fluctuation of the monthly mean values of the second cycle (Nov. 1978–Apr. 1979) was the similar pattern to that of the first cycle (Nov. 1977–Oct. 1978). However, the monthly mean value in March 1979 was slightly lower than that of the preceding year.

### In the nighttime

The monthly mean value in the nighttime was always lower than that in the daytime. Usually, it ranged from 0.1 to 0.2 g/28 $cm^2$/hr. The highest value of 0.23 g/28 $cm^2$/hr was obtained in October 1978. On the other hand, the lowest value of 0.06 g/28 $cm^2$/hr was observed in June 1978. There was no seasonal fluctuation between the monthly mean values in the nighttime.

## 7. Nutrients in seawater

**Ammonia-N** (Fig. 5)

The maximum value of ammonia-N at each point was 8.6 $\mu$g-at/$l$ at Point-A in January 1976, 8.6 at B in October 1978, 3.2 at C in October 1977, 1.8 at D in January 1977 and 4.3 at E in February 1977. No seasonal fluctuation was observed and a relatively high value (about 3.6 $\mu$g-at/$l$) was obtained regardless of the season at Points A-C.

**Nitrite-N**

Nitrite-N was not detected in almost all water samples, and the value of more than 0.4 $\mu$g-at/$l$ was not taken in all analyses.

**Nitrate-N** (Fig. 6)

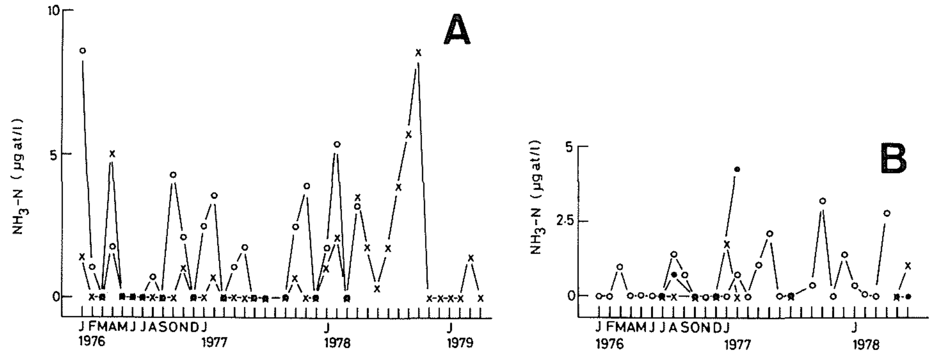


**Fig. 5** Seasonal fluctuation of ammonia-N in the seawaters of Charatsunai.
A: the Point-A (○) and the Point-B (×). B: the Point-C (○), the Point-D (×) and the Point-E (●).

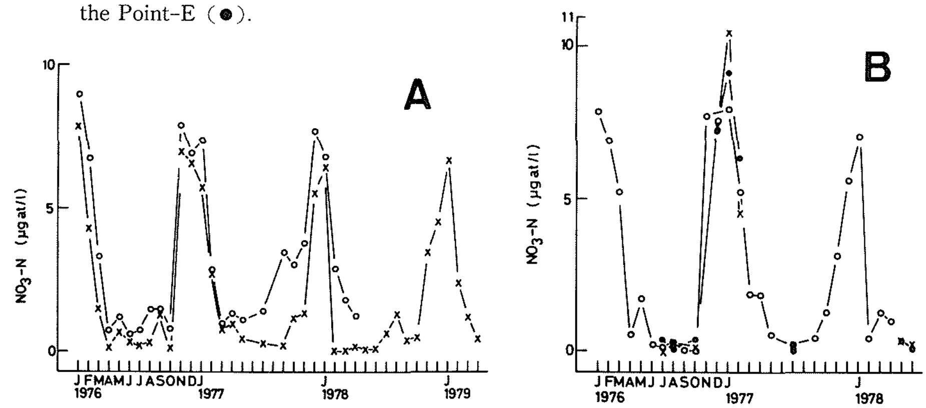


**Fig. 6** Seasonal fluctuation of nitrate-N in the seawaters of Charatsunai.
A: the Point-A (○) and the Point-B (×).
B: the Point-C (○), the Point-D (×) and the Point-E (●).

The maximum value of nitrate-N at each point was 9.0 $\mu$g-at/$l$ at Point-A in January 1976, 7.9 at B in January 1976, 7.9 at C in January 1977, 10.5 at D in January 1977 and 9.1 at E in January 1977. The seasonal fluctuation was observed. At all points, concentration of nitrate-N became higher in November or December and reached to the annual maximum of more than 7 $\mu$g-at/$l$ during November-January. Then, nitrate-N became poorer from February or March. A low concentration of this nutrient was usually detected from spring to middle autumn.

**Phosphate-P** (Fig. 7)

The maximum value of phosphate-P at each point was 1.1 $\mu$g-at/$l$ at Points A and B in February 1976, 1.26 at C in February 1976 and 0.97 at D and E in December 1976. The seasonal fluctuation was observed. At all points, phosphate-P became richer in November except 1977. In the case of 1977, the increment of phosphate-P began in December. The concentration of phosphate-P reached to the annual maximum of 1.0-1.3 $\mu$g-at/$l$ during November-February, and it decreased from March to April. A low concentration of this nutrient was detected from spring to middle autumn.

**Silicate-Si** (Fig. 8)

The maximum value of silicate-Si at each point was 24.7 $\mu$g-at/$l$ at Point-A in January 1977, 19.4 at D in February 1976, 71 at C in November 1977, 14.9 at D in December 1976 and 14.6 at E in December 1976. The seasonal fluctuation was observed at all points except C. Silicate-Si increased in November or December and its value attained the annual maximum of 14-25 $\mu$g-at/$l$ during December-February. This nutrient abruptly decreased from March or April. A low concentration of this nutrient was detected from spring to middle autumn.

It is known that silicate-Si is more abundant in land water than in seawater, and therefore a high concentration of Si is detected in coastal shore where land water pours

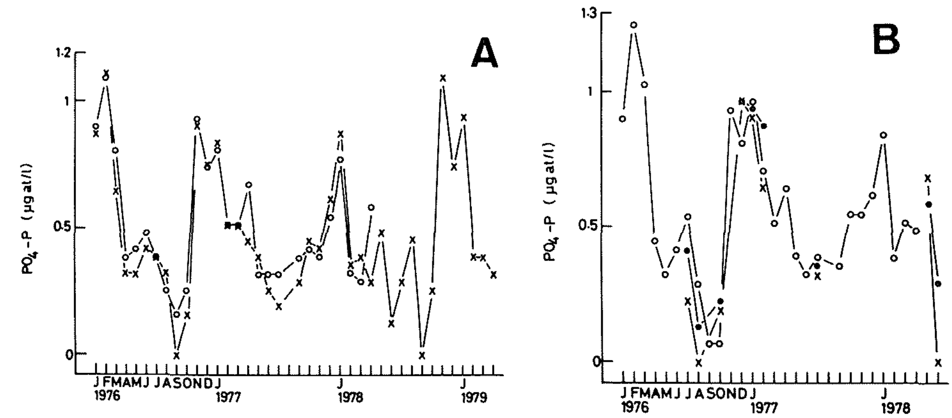


**Fig. 7** Seasonal fluctuation of phosphate-P in the seawaters of Charatsunai.
A : the Point-A (○) and the Point-B (×). B : the point-C (○), the Point-D (×) and the Point-E (●).

(Japan Meteorological Agency 1970). Land water pours near the Points A and C. Especially, a large quantity of land water pours into these points in a rainy day or in snow-thawing season. As a result, the high concentration of silicate-Si was detected in spring or summer.

The concentration of nitrate-N, phosphate-P and silicate-Si fluctuated seasonally in the same pattern. These three nutrients were rich from late autumn to early spring, but poor during other seasons.

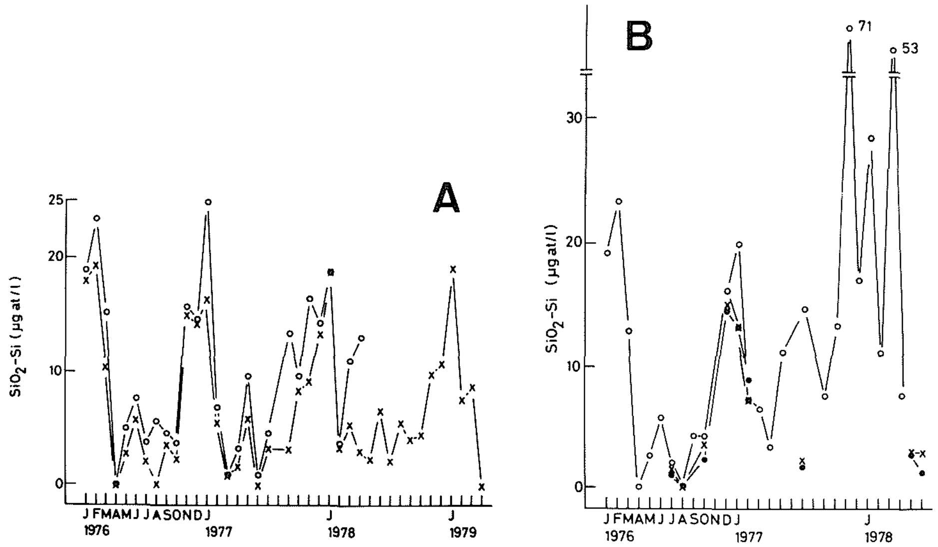


**Fig.** 8 Seasonal fluctuation of silicate-Si in the seawaters of Charatsunai. A: the point-A (○) and the Point-B (×). B: the Point-C (○), the Point-D (×) and the Point-E (●).

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**Table 1** Monthly mean air temperature (℃) at Charatsunai from April 1977 to April 1979.

| Month | Measurement time | | | |
|---|---|---|---|---|
| | 10 : 00 | 13 : 00 | 16 : 00 | 20 : 00 |
| April 1977 | 10.3(10)* | 12.5(11)* | 10.9(9)* | – |
| May | 11.9(10) | 15.5(10) | 14.1(10) | – |
| June | 17.3(13) | 19.6(14) | 17.4(13) | – |
| July | 18.9(12) | 21.0(13) | 18.6(9) | – |
| September | 20.8(9) | 22.1(9) | 21.4(9) | – |
| October | 17.7(10) | 20.3(11) | 17.7(11) | 12.9(9)* |
| November | 9.0(11) | 9.8(12) | 7.0(11) | 5.4(10) |
| December | 3.0(9) | 3.7(10) | 0.7(10) | 0.7(9) |
| January 1978 | 0.2(12) | 1.2(11) | −1.0(11) | −1.8(11) |
| February | −2.0(12) | −1.4(11) | −4.0(7) | −5.9(9) |
| March | 5.9(15) | 8.4(15) | 4.8(12) | 0.3(9) |
| April | 8.7(9) | 13.4(9) | 8.3(5) | 4.8(6) |
| May | 12.8(12) | 13.3(14) | 12.1(12) | 9.9(8) |
| June | 22.2(11) | 23.0(10) | 21.6(8) | 16.9(5) |
| July | 26.9(13) | 29.4(12) | 28.4(9) | 20.9(6) |
| August | 25.8(5) | 29.3(10) | 24.2(4) | 21.7(2) |
| September | 21.5(5) | 24.1(9) | 21.8 (5) | 17.2(5) |
| October | 15.2(9) | 16.1(11) | 13.9(7) | 10.6(7) |
| November | 8.6(13) | 9.6(13) | 8.1(9) | 5.3(9) |
| December | 4.1(9) | 4.7(10) | 2.6(5) | 0.7(5) |
| January 1979 | −2.0(4) | −1.6(6) | −2.3(6) | −3.8(7) |
| February | 0.6(12) | 3.0(12) | 0.1(10) | −3.1(6) |
| March | 5.3(14) | 6.5(15) | 4.7(8) | 0.1(7) |
| April | 7.7(10) | 9.6(10) | 9.1(8) | 3.7(4) |

* Values in brackets show the number of measurements.

**Table 2** Monthly mean seawater temperature (℃) at the Cleft-1 of Charatsunai from April 1977 to April 1979.

| Month | Measurement time | | | |
|---|---|---|---|---|
| | 10 : 00 | 13 : 00 | 16 : 00 | 20 : 00 |
| April 1977 | 6.2(10)* | 6.5(11)* | 6.5(9)* | – |
| May | 9.0(10) | 8.6(10) | 8.1(10) | – |
| June | 12.4(13) | 11.2(14) | 11.9(13) | – |
| July | 16.4(12) | 16.5(13) | 15.4(9) | – |
| August | 17.3** | – | – | – |
| September | 17.7(9) | 18.5(9) | 17.8(8) | – |
| October | 16.0(10) | 16.8(11) | 16.1(11) | 15.4(9)* |
| November | 11.0(11) | 11.4(12) | 11.1(11) | 9.4(10) |
| December | 7.9(9) | 8.4(10) | 8.1(10) | 7.0(9) |
| January 1978 | 4.5(12) | 4.8(11) | 4.6(11) | 4.1(11) |
| February | 1.5(12) | 2.3(11) | 1.9(7) | 0.8(9) |
| March | 2.1(15) | 3.1(15) | 2.8(12) | 0.9(9) |
| April | 4.6(9) | 6.7(9) | 4.1(5) | 2.7(6) |
| May | 9.9(12) | 10.6(14) | 9.6(12) | 8.2(8) |
| June | 17.0(11) | 16.7(10) | 13.3(8) | 12.4(5) |
| July | 20.4(13) | 20.6(12) | 20.5(9) | 18.0(6) |
| August | 19.7(5) | 20.9(5) | 18.7(4) | 18.1(2) |
| September | 18.5(5) | 18.8(6) | 18.7(5) | 17.8(5) |
| October | 14.6(9) | 14.9(10) | 14.6(7) | 14.0(7) |
| November | 11.1(13) | 11.5(13) | 11.3(9) | 10.3(9) |
| December | 7.7(9) | 8.3(10) | 8.0(5) | 7.6(5) |
| January 1979 | 5.1(4) | 4.5(6) | 4.5(6) | 2.4(7) |
| February | 2.6(12) | 3.3(11) | 2.9(10) | 2.2(6) |
| March | 2.4(14) | 3.7(11) | 2.5(8) | 1.5(7) |
| April | 4.0(10) | 4.5(9) | 4.0(8) | 2.7(4) |

* Values in brackets show the number of measurements.

** The datum was given by the Institute of Algological Research.

**Table 3** Seawater temperature (℃) at spring tide at Charatsunai from April 1977 to April 1979.

| Day | Time | Sampling point | | | | |
|---|---|---|---|---|---|---|
| | | C-1 | P-1 | P-2 | P-3 | P-4 |
| April 1977 | | | | | | |
| 4 | 10 : 00 | 9.0 | 13.4 | 12.4 | 12.0 | 12.2 |
| | 13 : 00 | 9.1 | | | | |
| | 16 : 00 | 6.4 | | | | |
| 5 | 10 : 00 | 8.3 | 16.1 | 13.8 | 14.8 | 15.3 |
| | 13 : 00 | 6.3 | 7.3 | 18.8 | 20.6 | 17.0 |
| | 16 : 00 | 7.0 | | | | |
| 6 | 10 : 00 | 9.5 | 12.8 | 14.0 | 14.2 | 13.4 |
| | 13 : 00 | 10.9 | 16.3 | 18.4 | 19.5 | 15.7 |
| | 16 : 00 | 8.1 | | | | |
| May 1977 | | | | | | |
| 4 | 10 : 00 | 16.5 | 16.8 | 18.0 | 17.1 | 17.0 |
| | 13 : 00 | 8.0 | 10.1 | 24.0 | 25.2 | 21.2 |
| | 16 : 00 | 7.7 | | | | |
| 6 | 10 : 00 | 8.4 | 8.6 | 9.0 | 9.3 | 10.1 |
| | 13 : 00 | 7.5 | 6.8 | 13.4 | 15.0 | 15.7 |
| | 16 : 00 | 6.7 | | | | |
| 7 | 10 : 00 | 6.3 | 6.3 | 7.2 | 7.4 | 8.4 |
| | 13 : 00 | 8.0 | 8.4 | 18.9 | 21.2 | 19.0 |
| | 16 : 00 | 7.6 | | | | |
| June 1977 | | | | | | |
| 14 | 10 : 00 | 11.8 | 12.8 | 19.9 | 19.4 | 17.8 |
| | 13 : 00 | 12.7 | | | | |
| | 16 : 00 | 11.0 | | | | |
| 15 | 10 : 00 | 12.0 | 16.3 | 16.3 | — | 15.3 |
| | 13 : 00 | 12.2 | | | | |
| | 16 : 00 | 10.7 | | | | |
| 16 | 10 : 00 | 17.3 | 21.8 | 21.8 | 20.4 | 21.2 |
| | 13 : 00 | 16.7 | | | | |
| | 16 : 00 | 13.2 | | | | |
| July 1977 | | | | | | |
| 13 | 10 : 00 | 16.1 | 16.0 | — | 18.6 | 19.0 |
| | 13 : 00 | 16.9 | | | | |
| 16 | 10 : 00 | 24.7 | 27.1 | 26.9 | 26.9 | 28.0 |
| | 13 : 00 | 19.9 | 23.8 | — | 28.7 | 27.8 |
| | 16 : 00 | 19.9 | | | | |
| 18 | 10 : 00 | 17.9 | 17.8 | 18.3 | 18.6 | 18.7 |
| | 13 : 00 | 17.5 | 17.3 | 19.3 | 19.4 | 19.9 |
| | 16 : 00 | 16.4 | | | | |
| September 1977 | | | | | | |
| 28 | 10 : 00 | 16.9 | 18.1 | 21.0 | 23.1 | 23.6 |
| 29 | 10 : 00 | 15.6 | 16.2 | 18.7 | 19.1 | 19.8 |
| | 13 : 00 | 16.5 | | | | |
| | 16 : 00 | 16.6 | | | | |
| 30 | 10 : 00 | 17.2 | | | 18.7 | |
| | 13 : 00 | 19.9 | | | | |
| | 16 : 00 | 17.8 | | | | |
| October 1977 | | | | | | |
| 11 | 10 : 00 | 15.2 | | | 17.3 | 16.2 |
| | 13 : 00 | 15.5 | | | | |
| | 16 : 00 | 15.1 | | | | |
| | 20 : 00 | 14.5 | 14.1 | 11.9 | 10.7 | 10.2 |

(*Continued*)

| Day | Time | Sampling point C-1 | P-1 | P-2 | P-3 | P-4 |
|---|---|---|---|---|---|---|
| 12 | 10 : 00 | 15.5 | 15.5 | 18.3 | 17.5 | 18.1 |
| | 13 : 00 | 16.1 | | | | |
| | 16 : 00 | 15.5 | | | | |
| | 20 : 00 | 14.9 | 14.5 | 13.2 | 12.8 | 11.6 |
| 13 | 10 : 00 | 15.9 | | | | |
| | 13 : 00 | 17.0 | | | | |
| | 16 : 00 | 16.4 | | | | |
| | 20 : 00 | 15.9 | 15.6 | 15.0 | 14.7 | 14.2 |
| November 1977 | | | | | | |
| 10 | 10 : 00 | 11.4 | | | | |
| | 13 : 00 | 11.6 | | | | |
| | 16 : 00 | 11.3 | | | | |
| | 20 : 00 | 6.6 | 5.6 | 5.4 | 5.1 | 2.8 |
| 11 | 10 : 00 | 10.4 | | | | |
| | 13 : 00 | 9.9 | | | | |
| | 16 : 00 | 9.9 | | | | |
| | 20 : 00 | 5.7 | 5.3 | 5.1 | 4.2 | 2.0 |
| 12 | 10 : 00 | 9.9 | | | 6.8 | |
| | 13 : 00 | 10.5 | | | | |
| | 16 : 00 | 10.6 | | | | |
| | 20 : 00 | 8.6 | 8.3 | 7.4 | 6.8 | 3.9 |
| December 1977 | | | | | | |
| 22 | 10 : 00 | 6.4 | | | | |
| | 13 : 00 | 8.3 | | | | |
| | 16 : 00 | 8.0 | | | | |
| | 20 : 00 | 4.7 | 2.2 | 1.6 | 1.6 | −1.3 |
| 23 | 10 : 00 | 6.8 | | | | |
| | 13 : 00 | 8.7 | | | | |
| | 16 : 00 | 8.4 | | | | |
| | 20 : 00 | 5.0 | 3.5 | 3.0 | 2.7 | −0.5 |
| 24 | 10 : 00 | 7.8 | | | | |
| | 13 : 00 | 8.7 | | | | |
| | 16 : 00 | 8.8 | | | | |
| | 20 : 00 | 7.9 | 7.5 | 6.3 | 5.7 | 3.9 |
| January 1978 | | | | | | |
| 23 | 10 : 00 | 3.6 | | | | |
| | 13 : 00 | 3.7 | | | | |
| | 16 : 00 | 3.5 | | | | |
| | 20 : 00 | 3.4 | | 1.7 | 1.2 | −0.5 |
| 24 | 10 : 00 | 3.1 | | | | |
| | 13 : 00 | 3.2 | | | | |
| | 16 : 00 | 3.2 | | | | |
| | 20 : 00 | 2.6 | | | 1.2 | |
| 25 | 10 : 00 | 2.5 | | | | |
| | 13 : 00 | 2.5 | | | | |
| | 16 : 00 | 2.8 | | | | |
| | 20 : 00 | 1.7 | | | 0.7 | |
| February 1978 | | | | | | |
| 20 | 10 : 00 | 1.8 | | | | |
| | 13 : 00 | 1.8 | | | | |
| | 20 : 00 | 0.8 | 0.7 | −1.4 | −0.8 | |
| 21 | 10 : 00 | 1.8 | | | | |
| | 13 : 00 | 2.4 | | | | |
| | 20 : 00 | 0.8 | 0.1 | −1.1 | −0.7 | −1.3 |

(*Continued*)

| Day | Time | Sampling point C-1 | P-1 | P-2 | P-3 | P-4 |
|---|---|---|---|---|---|---|
| 22 | 10 : 00 | 1.6 | | | | |
| | 13 : 00 | 1.7 | | | | |
| | 16 : 00 | 0.9 | | | | |
| | 20 : 00 | 0.2 | 0.2 | −0.6 | −0.6 | −1.4 |
| March 1978 | | | | | | |
| 25 | 10 : 00 | 2.2 | 5.4 | 11.0 | 9.7 | 11.6 |
| | 13 : 00 | 6.2 | | | | |
| 27 | 10 : 00 | 6.6 | 10.3 | 10.2 | 10.8 | 12.6 |
| | 13 : 00 | 3.4 | 8.7 | 17.1 | 17.6 | 17.6 |
| | 16 : 00 | 5.1 | | | | |
| | 20 : 00 | 1.4 | | | | |
| 29 | 10 : 00 | 2.2 | | | | |
| | 13 : 00 | 4.1 | 13.3 | 13.6 | 14.2 | 11.3 |
| | 16 : 00 | 6.6 | | | | |
| | 20 : 00 | 1.1 | | | | |
| April 1978 | | | | | | |
| 25 | 10 : 00 | 7.2 | 10.2 | 9.7 | 9.0 | 11.6 |
| | 13 : 00 | 6.5 | 11.1 | 17.6 | 18.3 | 18.3 |
| 27 | 10 : 00 | 4.3 | 5.0 | 6.6 | 7.4 | 8.3 |
| | 13 : 00 | 5.7 | 7.3 | 7.1 | 7.6 | 8.3 |
| | 16 : 00 | 4.7 | | | | |
| | 20 : 00 | 3.3 | | | | |
| 28 | 10 : 00 | 5.1 | | | | |
| | 13 : 00 | 15.0 | 18.4 | 18.7 | 18.6 | 19.2 |
| | 16 : 00 | 6.4 | 10.4 | 15.8 | 17.7 | 15.9 |
| | 20 : 00 | 5.1 | | | | |
| May 1978 | | | | | | |
| 24 | 10 : 00 | 8.4 | 8.5 | 8.6 | 8.6 | 8.7 |
| | 13 : 00 | 6.7 | 6.5 | 8.2 | 8.6 | 8.3 |
| | 16 : 00 | 6.4 | | | | |
| | 20 : 00 | 5.7 | | | | |
| 25 | 10 : 00 | 16.5 | 18.5 | 19.4 | 20.6 | 19.7 |
| | 13 : 00 | 19.0 | 24.8 | 26.9 | 25.9 | 23.9 |
| | 16 : 00 | 13.7 | | | | |
| | 20 : 00 | 8.5 | | | | |
| 26 | 13 : 00 | 13.6 | 13.8 | 14.5 | 15.2 | 15.2 |
| | 16 : 00 | 9.7 | | | | |
| | 20 : 00 | 7.8 | | | | |
| June 1978 | | | | | | |
| 21 | 10 : 00 | 15.4 | 15.9 | 15.5 | 15.9 | 16.7 |
| | 13 : 00 | 15.2 | | | 21.8 | |
| | 16 : 00 | 14.3 | | | | |
| 22 | 10 : 00 | 13.8 | 12.3 | 17.2 | 16.9 | 18.4 |
| | 13 : 00 | 11.2 | 12.3 | 21.0 | 20.4 | 20.5 |
| | 16 : 00 | 9.4 | | | | |
| | 20 : 00 | 11.6 | | | | |
| 23 | 10 : 00 | 22.4 | 25.2 | 24.7 | 24.2 | 25.5 |
| | 13 : 00 | 23.3 | 31.2 | 31.4 | | 29.1 |
| | 16 : 00 | 13.2 | | | | |
| July 1978 | | | | | | |
| 21 | 10 : 00 | 24.3 | 27.6 | 26.4 | 25.8 | 26.7 |
| | 13 : 00 | 21.2 | 29.4 | | 31.0 | 31.4 |
| | 16 : 00 | 19.8 | | | | |
| 22 | 10 : 00 | 21.3 | 22.9 | 22.6 | 22.4 | 23.3 |

*(Continued)*

| Day | Time | Sampling point C-1 | P-1 | P-2 | P-3 | P-4 |
|---|---|---|---|---|---|---|
| | 13 : 00 | 20.5 | 22.8 | 24.8 | 24.5 | 25.2 |
| 24 | 10 : 00 | 18.5 | 19.3 | 23.5 | 25.4 | 28.2 |
| | 13 : 00 | 19.5 | 26.7 | 31.7 | 31.9 | 30.1 |
| | 16 : 00 | 19.7 | | | | |
| | 20 : 00 | 15.9 | | | | |
| August 1978 | | | | | | |
| 16 | 10 : 00 | 15.2 | 16.3 | 23.0 | 22.8 | 23.2 |
| | 13 : 00 | 17.2 | | | | |
| | 16 : 00 | 17.9 | | | | |
| 18 | 10 : 00 | 19.2 | 29.4 | 29.0 | 26.7 | 28.1 |
| | 13 : 00 | 22.2 | | | | |
| | 16 : 00 | 18.1 | | | | |
| | 20 : 00 | 17.2 | | | | |
| 19 | 10 : 00 | 18.6 | 19.7 | 20.6 | 20.8 | 21.1 |
| | 13 : 00 | 18.0 | | | 21.3 | 21.6 |
| | 16 : 00 | 18.7 | | | | |
| September 1978 | | | | | | |
| 14 | 10 : 00 | 18.3 | | 19.8 | 20.2 | 20.1 |
| | 13 : 00 | 18.4 | | | | |
| | 16 : 00 | 18.2 | | | | |
| 16 | 10 : 00 | 18.7 | | | | |
| | 13 : 00 | 18.3 | | | | |
| | 20 : 00 | 18.1 | | | | |
| 18 | 10 : 00 | 17.6 | 17.5 | 20.2 | 22.1 | 21.6 |
| | 13 : 00 | 18.1 | | | | |
| | 16 : 00 | 18.3 | | | | |
| | 20 : 00 | 18.4 | | | | |
| October 1978 | | | | | | |
| 13 | 10 : 00 | 13.2 | | | | |
| | 13 : 00 | 14.0 | | | | |
| | 16 : 00 | 13.4 | | | | |
| | 20 : 00 | 12.1 | | | 8.9 | |
| 14 | 10 : 00 | 13.7 | | 14.1 | 14.8 | 13.1 |
| | 13 : 00 | 12.9 | | | | |
| 16 | 10 : 00 | 15.2 | | | | |
| | 13 : 00 | 15.0 | | | | |
| | 16 : 00 | 14.6 | | | | |
| 17 | 20 : 00 | 13.4 | 13.4 | 12.5 | 12.2 | 10.4 |
| November 1978 | | | | | | |
| 13 | 10 : 00 | 12.0 | | | 10.8 | 9.1 |
| | 13 : 00 | 12.6 | | | | |
| | 16 : 00 | 12.1 | | | | |
| | 20 : 00 | 10.2 | 7.8 | 8.2 | 7.4 | 5.4 |
| 14 | 10 : 00 | 11.1 | | | 11.2 | |
| | 13 : 00 | 12.3 | | | | |
| | 16 : 00 | 11.9 | | | | |
| | 20 : 00 | 10.7 | 9.7 | 9.1 | 8.4 | 6.7 |
| 15 | 10 : 00 | 11.9 | | | | |
| | 13 : 00 | 11.8 | | | | |
| | 16 : 00 | 11.8 | | | | |
| | 20 : 00 | 11.5 | 11.5 | 10.8 | 9.4 | 8.8 |
| December 1978 | | | | | | |
| 11 | 13 : 00 | 8.4 | | | | |
| | 20 : 00 | 6.8 | 3.0 | 2.7 | 2.6 | 0.1 |

(*Continued*)

| Day | Time | Sampling point C-1 | P-1 | P-2 | P-3 | P-4 |
|---|---|---|---|---|---|---|
| 13 | 10 : 00 | 8.7 | | | | |
| | 13 : 00 | 9.8 | | | | |
| | 16 : 00 | 9.7 | | | | |
| | 20 : 00 | 7.9 | 6.2 | 6.2 | 6.1 | 4.5 |
| 14 | 10 : 00 | 9.2 | | | | |
| | 13 : 00 | 9.4 | | | | |
| | 20 : 00 | 9.6 | 9.6 | 9.2 | 8.8 | 8.5 |
| January 1979 | | | | | | |
| 9 | 13 : 00 | 6.1 | | | | |
| | 16 : 00 | 5.7 | | | 4.5 | 1.2 |
| | 20 : 00 | 3.9 | −0.4 | 0.0 | 0.0 | −0.7 |
| 10 | 10 : 00 | 5.4 | | | | |
| | 13 : 00 | 5.9 | | | | |
| | 16 : 00 | 5.9 | | | | |
| | 20 : 00 | 4.4 | 4.0 | 0.6 | 0.6 | −0.3 |
| 11 | 10 : 00 | 4.2 | | | | |
| | 13 : 00 | 4.5 | | | | |
| | 16 : 00 | 4.2 | | | | |
| | 20 : 00 | 0.0 | 2.3 | −0.7 | −1.5 | −2.0 |
| February 1979 | | | | | | |
| 8 | 10 : 00 | 2.4 | | | | |
| | 13 : 00 | 2.7 | | | | |
| | 16 : 00 | 2.3 | | | | |
| | 20 : 00 | 1.1 | −1.5 | −0.9 | −1.3 | −1.5 |
| 9 | 10 : 00 | 2.2 | | | | |
| | 13 : 00 | 3.5 | | | | |
| | 16 : 00 | 3.5 | | | | |
| 13 | 10 : 00 | 2.7 | 3.1 | 2.6 | 3.0 | 1.8 |
| | 13 : 00 | 4.3 | | | | |
| | 16 : 00 | 3.2 | | | | |
| | 20 : 00 | 2.3 | | | 1.9 | |
| March 1979 | | | | | | |
| 14 | 10 : 00 | 2.7 | 3.3 | 6.4 | 7.5 | 6.2 |
| | 13 : 00 | 6.5 | | | | |
| | 16 : 00 | 2.5 | | | | |
| | 20 : 00 | 1.2 | | | 0.6 | |
| 15 | 10 : 00 | 2.9 | 3.7 | 7.2 | 8.0 | 5.3 |
| | 13 : 00 | 5.7 | | | | |
| | 16 : 00 | 3.7 | | | | |
| 16 | 13 : 00 | 4.7 | 3.0 | 7.7 | 12.0 | 9.8 |
| | 20 : 00 | 1.5 | | | | |
| April 1979 | | | | | | |
| 12 | 10 : 00 | 3.5 | 6.1 | 11.2 | 11.9 | 11.5 |
| | 13 : 00 | 5.8 | | | 10.6 | |
| | 16 : 00 | 4.3 | | | | |
| 13 | 10 : 00 | 7.2 | 11.1 | 12.7 | 12.2 | 11.4 |
| | 13 : 00 | 4.8 | 6.8 | 18.2 | 18.6 | 16.3 |
| | 16 : 00 | 5.2 | | | | |
| | 20 : 00 | 3.6 | | | | |
| 16 | 10 : 00 | 6.1 | 11.5 | 10.9 | 12.5 | 13.1 |
| | 13 : 00 | 4.4 | 13.2 | 12.5 | 14.6 | 15.2 |
| | 16 : 00 | 5.3 | | | | |
| | 20 : 00 | 2.9 | | | | |

**Table 4** Distribution of duration of tidal emersion at the level of 10 cm above the datum line at spring tide in Muroran.*

| Month | Emersion in the daytime | | | | | Emersion in the nighttime | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 0–0.5 | 0.5–1 | 1–2 | 2–3 | 3–4 hr | 0–0.5 | 0.5–1 | 1–2 | 2–3 | 3–4 hr |
| Nov. 1977 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 0 | 4 | 0 |
| Dec. | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 1 | 3 |
| Jan. 1978 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 3 | 1 |
| Feb. | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 1 | 0 | 0 |
| Mar. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Apr. | 0 | 0 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| May | 1 | 2 | 1 | 4 | 0 | 0 | 0 | 0 | 0 | 0 |
| June | 0 | 0 | 1 | 3 | 0 | 0 | 0 | 0 | 0 | 0 |
| July | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Aug. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Sep. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Oct. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

* Duration of emersion for 10 days at two spring tides per month was calculated from tide tables (Japan Meteorological Agency. 1976, 1977).

**Table 5** Distribution of duration of tidal emersion at the level of 40 cm above the datum line at spring tide in Muroran*.

| Month | Emersion in the daytime | | | | | | Emersion in the nighttime | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0–1 | 1–2 | 2–3 | 3–4 | 4–5 | 5–6 hr | 0–1 | 1–2 | 2–3 | 3–4 | 4–5 | 5–6 hr |
| Nov. 1977 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 7 | 2 |
| Dec. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 4 | 5 |
| Jan. 1978 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 3 | 5 |
| Feb. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 4 | 2 | 3 |
| Mar. | 1 | 1 | 0 | 3 | 2 | 0 | 1 | 0 | 0 | 2 | 3 | 0 |
| Apr. | 0 | 0 | 0 | 5 | 4 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| May | 0 | 0 | 0 | 2 | 6 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| June | 0 | 0 | 0 | 1 | 5 | 4 | 0 | 0 | 0 | 0 | 0 | 0 |
| July | 0 | 0 | 1 | 5 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Aug. | 0 | 1 | 5 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Sep. | 1 | 4 | 0 | 0 | 0 | 0 | 1 | 1 | 3 | 0 | 0 | 0 |
| Oct. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 9 | 0 | 0 |

* Duration of emersion for 10 days at two spring tides per month was calculated from tide tables (Japan Meteorological Agency, 1976, 1977).

**Table 6** Distribution of duration of tidal emersion at the level of 60 cm above the datum line at spring tide in Muroran*.

| Month | Emersion in the daytime | | | | | | | | Emersion in the nighttime | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0–1 | 1–2 | 2–3 | 3–4 | 4–5 | 5–6 | 6–7 | 7–8 hr | 0–1 | 1–2 | 2–3 | 3–4 | 4–5 | 5–6 | 6–7 | 7–8 hr |
| Nov. 1977 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 5 | 0 |
| Dec. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 5 | 4 |
| Jan. 1978 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 5 | 2 |
| Feb. | 2 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 3 | 5 | 0 |
| Mar. | 0 | 2 | 2 | 0 | 1 | 4 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 3 | 0 | 0 |
| Apr. | 0 | 0 | 0 | 0 | 0 | 8 | 1 | 1 | 2 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| May | 0 | 0 | 0 | 0 | 0 | 7 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| June | 0 | 0 | 0 | 0 | 1 | 0 | 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| July | 0 | 0 | 0 | 0 | 2 | 4 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Aug. | 0 | 0 | 0 | 1 | 3 | 6 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| Sep. | 0 | 0 | 1 | 3 | 3 | 0 | 0 | 0 | 0 | 1 | 1 | 2 | 3 | 0 | 0 | 0 |
| Oct. | 1 | 1 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 5 | 0 | 0 |

* Duration of emersion for 10 days at two spring tides per month was calculated from tide tables (Japan Meteorological Agency, 1976, 1977).

**Table 7** Distribution of duration of tidal emersion at the level of 80 cm above the datum line at spring tide in Muroran*.

| Month | Emersion in the daytime | | | | | | | | | Emersion in the nighttime | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0–1 | 1–2 | 2–3 | 3–4 | 4–5 | 5–6 | 6–7 | 7–8 | 8–9 hr | 0–1 | 1–2 | 2–3 | 3–4 | 4–5 | 5–6 | 6–7 | 7–8 | 8–9 hr |
| Nov. 1977 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 5 | 1 |
| Dec. | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 4 | 5 |
| Jan. 1978 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 2 | 5 |
| Feb. | 3 | 1 | 2 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 4 | 5 | 0 |
| Mar. | 1 | 1 | 2 | 2 | 1 | 0 | 4 | 1 | 0 | 0 | 1 | 0 | 1 | 2 | 2 | 3 | 1 | 0 |
| Apr. | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 3 | 1 | 0 | 1 | 2 | 4 | 2 | 0 | 0 | 0 | 0 |
| May | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 3 | 2 | 2 | 1 | 4 | 0 | 0 | 0 | 0 | 0 | 0 |
| June | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 6 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| July | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 8 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Aug. | 0 | 0 | 0 | 0 | 0 | 4 | 4 | 2 | 0 | 1 | 1 | 3 | 1 | 0 | 0 | 0 | 0 | 0 |
| Sep. | 0 | 1 | 0 | 2 | 3 | 3 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 2 | 5 | 0 | 0 | 0 |
| Oct. | 0 | 2 | 1 | 4 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 8 | 0 | 0 |

* Duration of emersion for 10 days at two spring tides per month was calculated from tide tables (Japan Meteorological Agency, 1976, 1977).

**Table 8** Seasonal change of frequency distribution of pH of seawater at the Cleft-1.

| Time | pH | | | | Total measurements |
|---|---|---|---|---|---|
| | 7.5–8.0 | 8.0–8.5 | 8.5–9.0 | 9.0–9.5 | |
| April 1977 | | | | | |
| 10 : 00 | 0% | 70% | 30% | 0% | 10 |
| 13 : 00 | 0 | 73 | 27 | 0 | 11 |
| 16 : 00 | 0 | 56 | 44 | 0 | 9 |
| 20 : 00 | | | | | |
| May 1977 | | | | | |
| 10 : 00 | 0 | 70 | 30 | 0 | 10 |
| 13 : 00 | 0 | 70 | 30 | 0 | 10 |
| 16 : 00 | 0 | 60 | 40 | 0 | 10 |
| 20 : 00 | | | | | |
| June 1977 | | | | | |
| 10 : 00 | 0 | 69 | 31 | 0 | 13 |
| 13 : 00 | 0 | 86 | 14 | 0 | 14 |
| 16 : 00 | 8 | 84 | 8 | 0 | 13 |
| 20 : 00 | | | | | |
| July 1977 | | | | | |
| 10 : 00 | 0 | 75 | 25 | 0 | 12 |
| 13 : 00 | 0 | 92 | 8 | 0 | 13 |
| 16 : 00 | 0 | 100 | 0 | 0 | 8 |
| 20 : 00 | | | | | |
| September 1977 | | | | | |
| 10 : 00 | 0 | 78 | 22 | 0 | 9 |
| 13 : 00 | 0 | 100 | 0 | 0 | 9 |
| 16 : 00 | 0 | 100 | 0 | 0 | 8 |
| 20 : 00 | | | | | |
| October 1977 | | | | | |
| 10 : 00 | 0 | 100 | 0 | 0 | 10 |
| 13 : 00 | 0 | 91 | 9 | 0 | 11 |
| 16 : 00 | 0 | 100 | 0 | 0 | 11 |
| 20 : 00 | 0 | 100 | 0 | 0 | 9 |
| November 1977 | | | | | |
| 10 : 00 | 0 | 100 | 0 | 0 | 11 |
| 13 : 00 | 0 | 100 | 0 | 0 | 12 |
| 16 : 00 | 0 | 100 | 0 | 0 | 11 |
| 20 : 00 | 50 | 50 | 0 | 0 | 10 |
| December 1977 | | | | | |
| 10 : 00 | 0 | 100 | 0 | 0 | 9 |
| 13 : 00 | 0 | 100 | 0 | 0 | 10 |
| 16 : 00 | 0 | 100 | 0 | 0 | 10 |
| 20 : 00 | 67 | 33 | 0 | 0 | 9 |
| January 1978 | | | | | |
| 10 : 00 | 0 | 100 | 0 | 0 | 12 |
| 13 : 00 | 0 | 100 | 0 | 0 | 11 |
| 16 : 00 | 9 | 91 | 0 | 0 | 11 |
| 20 : 00 | 27 | 73 | 0 | 0 | 11 |
| February 1978 | | | | | |
| 10 : 00 | 0 | 100 | 0 | 0 | 13 |
| 13 : 00 | 0 | 70 | 30 | 0 | 10 |
| 16 : 00 | 0 | 43 | 57 | 0 | 7 |
| 20 : 00 | 11 | 78 | 11 | 0 | 9 |
| March 1978 | | | | | |
| 10 : 00 | 0 | 93 | 7 | 0 | 15 |
| 13 : 00 | 0 | 60 | 40 | 0 | 15 |
| 16 : 00 | 0 | 58 | 42 | 0 | 12 |

*(Continued)*

| Time | 7.5 | 8.0 | pH 8.5 | 9.0 | 9.5 | Total measurements |
|---|---|---|---|---|---|---|
| 20 : 00 | 67 | 33 | 0 | 0 | | 9 |
| April 1978 | | | | | | |
| 10 : 00 | 0 | 50 | 50 | 0 | | 10 |
| 13 : 00 | 11 | 22 | 56 | 11 | | 9 |
| 16 : 00 | 0 | 60 | 40 | 0 | | 5 |
| 20 : 00 | 20 | 80 | 0 | 0 | | 5 |
| May 1978 | | | | | | |
| 10 : 00 | 0 | 92 | 8 | 0 | | 12 |
| 13 : 00 | 0 | 64 | 29 | 7 | | 14 |
| 16 : 00 | 0 | 83 | 17 | 0 | | 12 |
| 20 : 00 | 12 | 88 | 0 | 0 | | 8 |
| June 1978 | | | | | | |
| 10 : 00 | 0 | 36 | 64 | 0 | | 11 |
| 13 : 00 | 0 | 70 | 30 | 0 | | 10 |
| 16 : 00 | 0 | 75 | 25 | 0 | | 8 |
| 20 : 00 | 0 | 100 | 0 | 0 | | 5 |
| July 1978 | | | | | | |
| 10 : 00 | 0 | 69 | 31 | 0 | | 13 |
| 13 : 00 | 0 | 100 | 0 | 0 | | 12 |
| 16 : 00 | 0 | 100 | 0 | 0 | | 9 |
| 20 : 00 | 0 | 100 | 0 | 0 | | 6 |
| August 1978 | | | | | | |
| 10 : 00 | 0 | 100 | 0 | 0 | | 5 |
| 13 : 00 | 0 | 100 | 0 | 0 | | 5 |
| 16 : 00 | 0 | 100 | 0 | 0 | | 4 |
| 20 : 00 | 0 | 100 | 0 | 0 | | 2 |
| September 1978 | | | | | | |
| 10 : 00 | 0 | 100 | 0 | 0 | | 5 |
| 13 : 00 | 0 | 100 | 0 | 0 | | 6 |
| 16 : 00 | 0 | 100 | 0 | 0 | | 5 |
| 20 : 00 | 0 | 100 | 0 | 0 | | 5 |
| October 1978 | | | | | | |
| 10 : 00 | 0 | 100 | 0 | 0 | | 9 |
| 13 : 00 | 0 | 100 | 0 | 0 | | 10 |
| 16 : 00 | 0 | 100 | 0 | 0 | | 7 |
| 20 : 00 | 14 | 86 | 0 | 0 | | 7 |
| November 1978 | | | | | | |
| 10 : 00 | 0 | 100 | 0 | 0 | | 14 |
| 13 : 00 | 0 | 100 | 0 | 0 | | 12 |
| 16 : 00 | 0 | 100 | 0 | 0 | | 9 |
| 20 : 00 | 67 | 33 | 0 | 0 | | 9 |
| December 1978 | | | | | | |
| 10 : 00 | 0 | 100 | 0 | 0 | | 9 |
| 13 : 00 | 0 | 100 | 0 | 0 | | 10 |
| 16 : 00 | 0 | 100 | 0 | 0 | | 5 |
| 20 : 00 | 40 | 60 | 0 | 0 | | 5 |
| January 1979 | | | | | | |
| 10 : 00 | 0 | 100 | 0 | 0 | | 4 |
| 13 : 00 | 0 | 100 | 0 | 0 | | 6 |
| 16 : 00 | 0 | 100 | 0 | 0 | | 6 |
| 20 : 00 | 57 | 43 | 0 | 0 | | 7 |
| February 1979 | | | | | | |
| 10 : 00 | 17 | 83 | 0 | 0 | | 12 |
| 13 : 00 | 0 | 91 | 9 | 0 | | 11 |
| 16 : 00 | 10 | 90 | 0 | 0 | | 10 |
| 20 : 00 | 100 | 0 | 0 | 0 | | 6 |

*(Continued)*

| Time | 7.5 | | 8.0 | | pH 8.5 | | 9.0 | | 9.5 | Total measurements |
|---|---|---|---|---|---|---|---|---|---|---|
| March 1979 | | | | | | | | | | |
| 10 : 00 | | 14 | | 79 | | 7 | | 0 | | 14 |
| 13 : 00 | | 9 | | 64 | | 27 | | 0 | | 11 |
| 16 : 00 | | 25 | | 75 | | 0 | | 0 | | 8 |
| 20 : 00 | | 0 | | 100 | | 0 | | 0 | | 7 |
| April 1979 | | | | | | | | | | |
| 10 : 00 | | 0 | | 78 | | 22 | | 0 | | 9 |
| 13 : 00 | | 0 | | 75 | | 25 | | 0 | | 8 |
| 16 : 00 | | 0 | | 75 | | 25 | | 0 | | 8 |
| 20 : 00 | | 50 | | 50 | | 0 | | 0 | | 4 |

**Table 9** pH of seawater at spring tide at Charatsunai from April 1977 to April 1979.

| Time | | Sampling point C-1 | P-1 | P-2 | P-3 | P-4 |
|---|---|---|---|---|---|---|
| April 1977 | | | | | | |
| 4 | 10 : 00 | 8.89 | 8.78 | | | 9.85 |
| | 13 : 00 | 8.60 | | | | |
| | 16 : 00 | 8.23 | | | | |
| 5 | 10 : 00 | 8.83 | 8.76 | | | 9.92 |
| | 13 : 00 | 8.49 | 8.45 | | | 9.52 |
| | 16 : 00 | 8.36 | | | | |
| 6 | 10 : 00 | 8.83 | 8.87 | | | 9.85 |
| | 13 : 00 | 8.75 | 8.86 | | | 9.69 |
| | 16 : 00 | 8.51 | | | | |
| May 1977 | | | | | | |
| 4 | 10 : 00 | 8.92 | 9.19 | | | 9.90 |
| | 13 : 00 | 8.50 | 8.59 | | | 9.50 |
| | 16 : 00 | 8.30 | | | | |
| 6 | 10 : 00 | 8.60 | 8.62 | | | 9.44 |
| | 13 : 00 | 8.40 | 8.31 | | | 9.50 |
| | 16 : 00 | 8.18 | | | | |
| 7 | 10 : 00 | 8.18 | 8.22 | | | 8.80 |
| | 13 : 00 | 8.38 | 8.41 | | | 9.78 |
| | 16 : 00 | 8.23 | | | | |
| June 1977 | | | | | | |
| 14 | 10 : 00 | 8.50 | 8.62 | | | 9.00 |
| | 13 : 00 | 8.34 | | | | |
| | 16 : 00 | 8.21 | | | | |
| 15 | 10 : 00 | 8.59 | 8.76 | | | 9.10 |
| | 13 : 00 | 8.50 | | | | |
| | 16 : 00 | 8.21 | | | | |
| 16 | 10 : 00 | 8.79 | 8.82 | | | 9.07 |
| | 13 : 00 | 8.45 | | | | |
| | 16 : 00 | 8.30 | | | | |
| July 1977 | | | | | | |
| 13 | 10 : 00 | 8.52 | 8.49 | | | 8.71 |
| | 13 : 00 | 8.26 | | | | |
| 16 | 10 : 00 | 8.85 | 8.70 | | | 8.91 |
| | 13 : 00 | 8.50 | 8.51 | | | 8.91 |
| | 16 : 00 | 8.33 | | | | |
| 18 | 10 : 00 | 8.48 | 8.41 | | | 8.51 |
| | 13 : 00 | 8.25 | 8.29 | | | 8.82 |
| | 16 : 00 | 8.10 | | | | |
| September 1977 | | | | | | |
| 28 | 10 : 00 | 8.52 | 8.54 | | | 9.07 |

(*Continued*)

| Time | | C-1 | P-1 | P-2 | P-3 | P-4 |
|---|---|---|---|---|---|---|
| | | Sampling point | | | | |
| 29 | 10 : 00 | 8.32 | 8.49 | | | 9.03 |
| | 13 : 00 | 8.23 | | | | |
| | 16 : 00 | 8.21 | | | | |
| 30 | 10 : 00 | 8.29 | | | | |
| | 13 : 00 | 8.40 | | | | |
| | 16 : 00 | 8.34 | | | | |
| October 1977 | | | | | | |
| 11 | 10 : 00 | 8.29 | 8.30 | | | 9.19 |
| | 13 : 00 | 8.29 | | | | |
| | 16 : 00 | 8.22 | | | | |
| | 20 : 00 | 8.10 | 8.10 | | | 7.50 |
| 12 | 10 : 00 | 8.39 | 8.39 | | | 9.08 |
| | 13 : 00 | 8.32 | | | | |
| | 16 : 00 | 8.28 | | | | |
| | 20 : 00 | 8.15 | 8.12 | | | 7.50 |
| 13 | 10 : 00 | 8.38 | | | | |
| | 13 : 00 | 8.40 | | | | |
| | 16 : 00 | 8.32 | | | | |
| | 20 : 00 | 8.18 | 8.18 | | | 7.62 |
| November 1977 | | | | | | |
| 10 | 10 : 00 | 8.32 | | | | |
| | 13 : 00 | 8.19 | | | | |
| | 16 : 00 | 8.17 | | | | |
| | 20 : 00 | 7.74 | 7.71 | | | 7.51 |
| 11 | 10 : 00 | 8.29 | | | | |
| | 13 : 00 | 8.14 | | | | |
| | 16 : 00 | 8.15 | | | | |
| | 20 : 00 | 7.70 | 7.75 | | | 7.50 |
| 12 | 10 : 00 | 8.29 | | | | |
| | 13 : 00 | 8.29 | | | | |
| | 16 : 00 | 8.11 | | | | |
| | 20 : 00 | 7.84 | 7.83 | | | 7.49 |
| December 1977 | | | | | | |
| 22 | 10 : 00 | 8.13 | | | | |
| | 13 : 00 | 8.20 | | | | |
| | 16 : 00 | 8.13 | | | | |
| | 20 : 00 | 7.80 | 7.67 | 7.83 | | 8.52 |
| 23 | 10 : 00 | 8.12 | | | | |
| | 13 : 00 | 8.16 | | | | |
| | 16 : 00 | 8.21 | | | | |
| | 20 : 00 | 7.81 | 7.64 | 7.89 | | 8.29 |
| 24 | 10 : 00 | 8.03 | | | | |
| | 13 : 00 | 8.17 | | | | |
| | 16 : 00 | 8.17 | | | | |
| | 20 : 00 | 7.93 | 7.90 | 7.90 | | 7.41 |
| January 1978 | | | | | | |
| 23 | 10 : 00 | 8.17 | | | | |
| | 13 : 00 | 8.09 | | | | |
| | 16 : 00 | 8.12 | | | | |
| | 20 : 00 | 7.96 | | 7.87 | | 7.51 |
| 24 | 10 : 00 | 8.18 | | | | |
| | 13 : 00 | 8.11 | | | | |
| | 16 : 00 | 8.03 | | | | |
| | 20 : 00 | 8.01 | | | | |
| 25 | 10 : 00 | 8.06 | | | | |
| | 13 : 00 | 8.13 | | | | |
| | 16 : 00 | 7.97 | | | | |

*(Continued)*

| Time | | C-1 | P-1 | P-2 | P-3 | P-4 |
|---|---|---|---|---|---|---|
| | | | | Sampling point | | |
| | 20 : 00 | 8.03 | | | | |
| February 1978 | | | | | | |
| 20 | 10 : 00 | 8.35 | | | | |
| | 13 : 00 | 8.38 | | | | |
| | 20 : 00 | 8.16 | 8.10 | 7.98 | | |
| 21 | 10 : 00 | 8.23 | | | | |
| | 13 : 00 | 8.30 | | | | |
| | 20 : 00 | 8.05 | 7.98 | 7.90 | | 7.70 |
| 22 | 10 : 00 | 8.42 | | | | |
| | 13 : 00 | 8.31 | | | | |
| | 16 : 00 | 8.13 | | | | |
| | 20 : 00 | 8.00 | 7.89 | 7.89 | | 7.58 |
| March 1978 | | | | | | |
| 25 | 10 : 00 | 8.46 | 8.74 | 8.77 | | 9.10 |
| | 13 : 00 | 8.70 | | | | |
| 27 | 10 : 00 | 8.92 | 8.75 | 8.70 | | 9.08 |
| | 13 : 00 | 8.42 | 8.90 | 8.98 | | 8.95 |
| | 16 : 00 | 8.50 | | | | |
| | 20 : 00 | 7.92 | | | | |
| 29 | 10 : 00 | 8.42 | | | | |
| | 13 : 00 | 8.68 | 9.10 | 9.02 | | 9.27 |
| | 16 : 00 | 8.89 | | | | |
| | 20 : 00 | 8.11 | | | | |
| April 1978 | | | | | | |
| 25 | 10 : 00 | 8.90 | 9.08 | 8.86 | | 9.19 |
| | 13 : 00 | 8.65 | 8.91 | 8.82 | | 9.12 |
| 27 | 10 : 00 | 8.60 | 8.66 | 8.69 | | 9.27 |
| | 13 : 00 | 8.72 | 8.95 | 8.71 | | 9.23 |
| | 16 : 00 | 8.48 | | | | |
| | 20 : 00 | 8.11 | | | | |
| 28 | 10 : 00 | 8.49 | | | | |
| | 13 : 00 | 9.39 | 9.20 | 8.92 | | 9.20 |
| | 16 : 00 | 8.70 | 8.82 | 8.95 | | 8.95 |
| | 20 : 00 | 8.26 | | | | |
| May 1978 | | | | | | |
| 24 | 10 : 00 | 8.40 | 8.30 | 8.21 | | 8.31 |
| | 13 : 00 | 8.12 | 8.10 | 8.37 | | 8.30 |
| | 16 : 00 | 8.08 | | | | |
| | 20 : 00 | 8.00 | | | | |
| 25 | 10 : 00 | 8.92 | 8.64 | 8.48 | | 9.10 |
| | 13 : 00 | 8.81 | 8.58 | 8.84 | | 9.09 |
| | 16 : 00 | 8.39 | | | | |
| | 20 : 00 | 8.11 | | | | |
| 26 | 13 : 00 | 9.00 | 8.54 | 8.65 | | 9.00 |
| | 16 : 00 | 8.41 | | | | |
| | 20 : 00 | 8.08 | | | | |
| June 1978 | | | | | | |
| 21 | 10 : 00 | 8.61 | 8.49 | 8.39 | | 8.80 |
| | 13 : 00 | 8.42 | | | | |
| | 16 : 00 | 8.30 | | | | |
| 22 | 10 : 00 | 8.68 | 8.43 | 8.21 | | 9.13 |
| | 13 : 00 | 8.47 | 8.46 | 8.42 | | 9.11 |
| | 16 : 00 | 8.20 | | | | |
| | 20 : 00 | 8.15 | | | | |
| 23 | 10 : 00 | 8.95 | 8.70 | 8.20 | | 9.12 |
| | 13 : 00 | 8.68 | 8.47 | 8.18 | | 9.19 |
| | 16 : 00 | 8.32 | | | | |

(*Continued*)

| Time | | C-1 | P-1 | Sampling point P-2 | P-3 | P-4 |
|---|---|---|---|---|---|---|
| July 1978 | | | | | | |
| 21 | 10 : 00 | 8.79 | 8.60 | 8.32 | | 9.22 |
| | 13 : 00 | 8.39 | 8.47 | | | 9.16 |
| | 16 : 00 | 8.21 | | | | |
| 22 | 10 : 00 | 8.58 | 8.50 | 8.11 | | 9.04 |
| | 13 : 00 | 8.34 | 8.55 | 8.25 | | 9.17 |
| 24 | 10 : 00 | 8.32 | 8.33 | 8.29 | | 9.20 |
| | 13 : 00 | 8.40 | 8.65 | 8.42 | | 9.21 |
| | 16 : 00 | 8.33 | | | | |
| | 20 : 00 | 8.10 | | | | |
| August 1978 | | | | | | |
| 16 | 10 : 00 | 8.25 | 8.35 | 8.50 | | 9.07 |
| | 13 : 00 | 8.31 | | | | |
| | 16 : 00 | 8.29 | | | | |
| 18 | 10 : 00 | 8.40 | 8.60 | 8.39 | | 9.09 |
| | 13 : 00 | 8.35 | | | | |
| | 16 : 00 | 8.25 | | | | |
| | 20 : 00 | 8.16 | | | | |
| 19 | 10 : 00 | 8.29 | 8.37 | 8.39 | | 8.59 |
| | 13 : 00 | 8.19 | | | | 8.88 |
| | 16 : 00 | 8.19 | | | | |
| September 1978 | | | | | | |
| 14 | 10 : 00 | 8.30 | 8.50 | 8.38 | | 9.20 |
| | 13 : 00 | 8.30 | | | | |
| | 16 : 00 | 8.24 | | | | |
| 16 | 10 : 00 | 8.28 | | | | |
| | 13 : 00 | 8.22 | | | | |
| | 20 : 00 | 8.19 | | | | |
| 18 | 10 : 00 | 8.33 | 8.30 | 8.58 | | 9.23 |
| | 13 : 00 | 8.28 | | | | |
| | 16 : 00 | 8.27 | | | | |
| | 20 : 00 | 8.20 | | | | |
| October 1978 | | | | | | |
| 13 | 10 : 00 | 8.30 | | | | |
| | 13 : 00 | 8.19 | | | | |
| | 16 : 00 | 8.13 | | | | |
| | 20 : 00 | 8.00 | | | 7.98 | |
| 14 | 10 : 00 | 8.29 | | 8.40 | 8.40 | 9.30 |
| | 13 : 00 | 8.10 | | | | |
| 16 | 10 : 00 | 8.16 | | | | |
| | 13 : 00 | 8.13 | | | | |
| | 16 : 00 | 8.12 | | | | |
| 17 | 20 : 00 | 7.99 | 8.06 | 7.98 | 8.02 | 7.40 |
| November 1978 | | | | | | |
| 13 | 10 : 00 | 8.22 | | | 8.23 | 8.88 |
| | 13 : 00 | 8.24 | | | | |
| | 16 : 00 | 8.22 | | | | |
| | 20 : 00 | 7.69 | 7.39 | 7.73 | 7.99 | 7.47 |
| 14 | 10 : 00 | 8.17 | | | 8.32 | |
| | 13 : 00 | 8.19 | | | | |
| | 16 : 00 | 8.19 | | | | |
| | 20 : 00 | 7.80 | 7.78 | 7.73 | 8.00 | 7.40 |
| 15 | 10 : 00 | 8.08 | | | | |
| | 13 : 00 | 8.08 | | | | |
| | 16 : 00 | 8.06 | | | | |
| | 20 : 00 | 7.98 | 8.00 | 7.91 | 7.98 | 7.48 |

*(Continued)*

| Time | | C-1 | Sampling point P-1 | P-2 | P-3 | P-4 |
|---|---|---|---|---|---|---|
| December 1978 | | | | | | |
| 11 | 13 : 00 | 8.30 | | | | |
| | 20 : 00 | 7.99 | 7.73 | 7.83 | 7.89 | 7.80 |
| 13 | 10 : 00 | 8.28 | | | | |
| | 13 : 00 | 8.31 | | | | |
| | 16 : 00 | 8.30 | | | | |
| | 20 : 00 | 7.80 | 7.70 | 7.82 | 8.04 | 7.51 |
| 14 | 10 : 00 | 8.26 | | | | |
| | 13 : 00 | 8.25 | | | | |
| | 20 : 00 | 8.09 | 8.11 | 8.00 | 8.12 | 7.61 |
| January 1979 | | | | | | |
| 9 | 13 : 00 | 8.22 | | | | |
| | 16 : 00 | 8.13 | | | 8.34 | 9.51 |
| | 20 : 00 | 8.00 | 7.80 | 7.88 | 8.21 | 8.98 |
| 10 | 10 : 00 | 8.06 | | | | |
| | 13 : 00 | 8.14 | | | | |
| | 16 : 00 | 8.10 | | | | |
| | 20 : 00 | 7.99 | 7.99 | 7.81 | 7.83 | 7.59 |
| 11 | 10 : 00 | 8.08 | | | | |
| | 13 : 00 | 8.10 | | | | |
| | 16 : 00 | 8.10 | | | | |
| | 20 : 00 | 7.96 | 8.00 | 7.84 | 7.80 | 7.55 |
| February 1979 | | | | | | |
| 8 | 10 : 00 | 8.08 | | | | |
| | 13 : 00 | 8.00 | | | | |
| | 16 : 00 | 8.11 | | | | |
| | 20 : 00 | 7.88 | 7.63 | 7.68 | 7.90 | 7.99 |
| 9 | 10 : 00 | 8.12 | | | | |
| | 13 : 00 | 8.34 | | | | |
| | 16 : 00 | 8.23 | | | | |
| 13 | 10 : 00 | 8.05 | 8.25 | 8.30 | 8.48 | 8.81 |
| | 13 : 00 | 8.30 | | | | |
| | 16 : 00 | 8.13 | | | | |
| | 20 : 00 | 7.98 | | | 7.95 | |
| March 1979 | | | | | | |
| 14 | 10 : 00 | 8.33 | 8.40 | 8.55 | 8.50 | 9.00 |
| | 13 : 00 | 8.61 | | | | |
| | 16 : 00 | 8.11 | | | | |
| | 20 : 00 | 7.85 | | | 7.85 | |
| 15 | 10 : 00 | 8.47 | 8.48 | 8.55 | 8.62 | 8.94 |
| | 13 : 00 | 8.70 | | | | |
| | 16 : 00 | 8.40 | | | | |
| 16 | 13 : 00 | 8.60 | 8.28 | 8.72 | 8.90 | 9.25 |
| | 20 : 00 | 7.90 | | | | |
| April 1979 | | | | | | |
| 12 | 10 : 00 | 8.39 | 8.59 | 9.18 | 8.57 | 9.10 |
| | 13 : 00 | 8.38 | | | 8.48 | |
| | 16 : 00 | 8.24 | | | | |
| 13 | 10 : 00 | 8.80 | 9.08 | 8.69 | 8.54 | 9.10 |
| | 13 : 00 | 8.38 | 8.54 | 8.90 | 8.79 | 9.00 |
| | 16 : 00 | 8.38 | | | | |
| | 20 : 00 | 8.18 | | | | |
| 16 | 10 : 00 | 8.79 | 9.03 | 8.82 | 8.70 | 9.24 |
| | 13 : 00 | 8.50 | 9.11 | 8.86 | 8.87 | 9.12 |
| | 16 : 00 | 8.54 | | | | |
| | 20 : 00 | 8.01 | | | | |

**Table 10** Salinity (‰) of seawater at the lower low water of spring tide.

| Time | | Weather | Sampling point C-1 | P-1 | P-2 | P-3 | P-4 |
|---|---|---|---|---|---|---|---|
| February 1978 | | | | | | | |
| 21 | 20 : 22 | F | 32.59 | 32.68 | 33.04 | | 34.14 |
| 22 | 21 : 00 | S | 32.70 | 32.57 | 32.70 | | 34.52 |
| 23 | 21 : 25 | C | 32.55 | 33.08 | 33.40 | | 34.94 |
| 27 | 11 : 29 | S | 32.43 | 32.37 | 32.37 | | 32.57 |
| 28 | 12 : 12 | S | 32.45 | 32.43 | 32.39 | | 32.64 |
| March 1978 | | | | | | | |
| 1 | 13 : 01 | C | 32.26 | 32.21 | 32.23 | | 32.01 |
| 2 | 14 : 02 | F | 32.39 | 32.39 | 32.64 | | 33.26 |
| 3 | 16 : 00 | C | 32.41 | 32.48 | 32.57 | | 33.29 |
| 8 | 20 : 28 | F | 32.26 | 32.37 | 32.25 | | 33.04 |
| 9 | 21 : 09 | F | 32.26 | 32.37 | 32.28 | | 33.73 |
| 13 | 11 : 17 | SC | 32.30 | 32.32 | 32.32 | | 32.55 |
| 14 | 12 : 00 | F | 32.37 | 32.43 | 32.48 | | 32.79 |
| 22 | 19 : 56 | S | 32.32 | 32.26 | 32.08 | | 32.21 |
| 24 | 21 : 03 | F | 32.32 | 32.32 | 32.26 | | 32.34 |
| 27 | 10 : 31 | F | 32.48 | 32.54 | 32.26 | | 32.79 |
| 28 | 11 : 12 | C | 32.43 | 32.54 | 32.12 | | 32.66 |
| 29 | 11 : 56 | F | 32.32 | 32.61 | 32.41 | | 33.48 |
| April 1978 | | | | | | | |
| 11 | 10 : 58 | F | 32.54 | 32.70 | 32.66 | | 33.01 |
| 12 | 11 : 27 | Sl | 32.16 | 32.30 | 30.55 | | 28.53 |
| 13 | 12 : 09 | C | 32.45 | 32.57 | 32.43 | | 32.75 |
| 25 | 10 : 14 | | 32.28 | 32.34 | 32.34 | | 32.39 |
| 27 | 11 : 36 | C | 31.78 | 31.98 | 32.12 | | 32.36 |
| 28 | 12 : 18 | F | 31.96 | 32.03 | 32.14 | | 32.34 |
| May 1978 | | | | | | | |
| 8 | 9 : 21 | F | 32.28 | 32.55 | 32.41 | | 32.66 |
| 9 | 10 : 01 | C | 32.14 | 32.23 | 32.34 | | 32.45 |
| 11 | 11 : 09 | F | 31.38 | 31.38 | 31.42 | | 31.58 |
| 24 | 10 : 00 | C | 31.45 | 31.51 | 31.58 | | 31.47 |
| 25 | 10 : 40 | F | 31.80 | 32.30 | 32.25 | | 32.43 |
| 26 | 11 : 19 | Fog | 31.51 | 31.74 | 31.65 | | 31.74 |
| June 1978 | | | | | | | |
| 7 | 9 : 39 | F | 32.45 | 32.92 | 32.61 | | 33.01 |
| 8 | 10 : 13 | F | 32.66 | 33.29 | 32.81 | | 33.40 |
| 9 | 10 : 53 | F | 32.61 | 33.35 | 32.75 | | 33.29 |
| 21 | 9 : 05 | Fog | 14.24 | 21.95 | 19.84 | | 15.86 |
| 22 | 9 : 47 | C | 31.94 | 32.01 | 31.56 | | 31.96 |
| 23 | 10 : 22 | F | 30.84 | 31.45 | 31.47 | | 31.49 |
| July 1978 | | | | | | | |
| 6 | 9 : 21 | SC | 31.60 | 31.80 | 31.80 | | 31.96 |
| 7 | 10 : 00 | R | 24.12 | 27.62 | 17.38 | | 14.15 |
| 8 | 10 : 26 | F | 31.65 | 31.89 | 31.54 | | 32.30 |
| 20 | 8 : 54 | C | 31.99 | 32.07 | 31.85 | | 32.08 |
| 21 | 9 : 26 | C | 32.26 | 32.61 | 32.48 | | 32.45 |
| 22 | 10 : 11 | Fog | 32.23 | 32.21 | 32.21 | | 32.03 |
| August 1978 | | | | | | | |
| 4 | 9 : 08 | R | 31.85 | 32.01 | 31.87 | | 31.42 |
| 5 | 9 : 32 | F | 32.32 | 32.46 | 32.64 | | 32.75 |
| 7 | 10 : 44 | F | 32.25 | 32.30 | 32.34 | | 32.52 |
| 18 | 8 : 28 | F | 32.43 | 32.57 | 32.26 | | 32.55 |
| 19 | 9 : 19 | C | 32.43 | 32.50 | 32.43 | | 32.39 |
| September 1978 | | | | | | | |
| 2 | 8 : 38 | F | 33.46 | 33.60 | 33.69 | | 33.84 |
| 3 | 9 : 11 | C | 33.53 | 33.60 | 33.66 | | 33.76 |
| 4 | 9 : 45 | F | 33.67 | 33.71 | 33.85 | | 34.51 |

(*Continued*)

| Time | | Weather | Sampling point C-1 | P-1 | P-2 | P-3 | P-4 |
|---|---|---|---|---|---|---|---|
| October 1978 | | | | | | | |
| 4 | 22 : 12 | F | 33.71 | 33.69 | 33.85 | 33.95 | 33.98 |
| 5 | 22 : 53 | C | 33.82 | 33.73 | 33.80 | 33.93 | 34.02 |
| 17 | 21 : 21 | F | 33.71 | 33.82 | 33.76 | 33.93 | 33.95 |
| November 1978 | | | | | | | |
| 2 | 21 : 56 | F | 33.60 | 33.69 | 33.71 | 33.76 | 33.95 |
| 14 | 20 : 28 | F | 33.49 | 33.75 | 33.64 | 33.71 | 33.80 |
| 15 | 21 : 09 | C | 33.76 | 33.67 | 33.71 | 33.33 | 33.98 |
| 29 | 20 : 18 | R | 33.44 | 33.40 | 33.13 | 33.33 | 33.19 |
| 30 | 21 : 01 | F | 33.42 | 33.40 | 33.31 | 33.46 | 33.48 |
| December 1978 | | | | | | | |
| 13 | 20 : 21 | F | 33.76 | 33.87 | 33.82 | 33.89 | 33.85 |
| 14 | 21 : 00 | R | 31.81 | 31.24 | 30.12 | 31.20 | 28.44 |
| 28 | 20 : 06 | | 31.98 | 32.41 | 32.83 | 31.76 | 32.36 |
| January 1979 | | | | | | | |
| 11 | 20 : 21 | S | 33.66 | 33.64 | 36.98 | 37.94 | 41.44 |
| 12 | 20 : 51 | SC | 33.69 | 35.07 | 36.04 | 36.87 | 39.06 |
| 26 | 19 : 55 | C | 33.19 | 32.90 | 33.01 | 32.95 | 32.95 |
| February 1979 | | | | | | | |
| 9 | 20 : 19 | F | 32.99 | 33.31 | 33.31 | 33.15 | 37.11 |
| 23 | 18 : 49 | F | 32.99 | 33.02 | 32.99 | 33.22 | 38.23 |
| 26 | 21 : 00 | S | 32.84 | 32.83 | 32.72 | 32.70 | 32.83 |
| March 1979 | | | | | | | |
| 19 | 12 : 12 | F | 32.57 | 32.72 | 32.72 | 32.75 | 33.01 |
| 26 | 19 : 55 | C | 32.55 | 32.50 | 32.66 | 32.61 | 32.63 |
| 30 | 10 : 09 | R | 32.39 | 32.26 | 32.16 | 32.10 | 31.98 |
| April 1979 | | | | | | | |
| 16 | 11 : 13 | SC | 32.39 | 32.77 | 32.79 | 32.57 | 32.93 |
| 18 | 12 : 40 | SC | 32.14 | 32.23 | 32.45 | 32.92 | 33.04 |

F : fine weather ; SC : slightly cloudy ; C : cloudy ; R : rainy ;
S : snowy ; Sl : sleety.

**Table 11** Monthly mean evaporation value of water ($g/28cm^2/hr$) at Charatsunai from November 1977 to April 1979.

| Month | In daytime | In nighttime |
|---|---|---|
| November 1977 | 0.37(7*) | 0.10(6*) |
| December | 0.28(10) | 0.14(9) |
| January 1978 | 0.20(12) | 0.13(11) |
| February | 0.24(9) | 0.17(9) |
| March | 0.54(14) | 0.13(8) |
| April | 0.39(9) | 0.15(6) |
| May | 0.31(13) | 0.09(7) |
| June | 0.50(10) | 0.06(5) |
| July | 0.66(12) | — |
| August | 0.88(9) | — |
| September | 0.74(9) | 0.15(5) |
| October | 0.51(10) | 0.23(7) |
| November | 0.38(12) | 0.13(9) |
| December | 0.28(9) | 0.14(5) |
| January 1979 | 0.26(4) | 0.21(7) |
| February | 0.27(12) | 0.18(7) |
| March | 0.38(16) | 0.11(7) |
| April | 0.40(9) | 0.15(4) |

* Values in brackets show the number of measurements.