3.7 Bottom Sediment

(1) Purpose

The purpose of bottom sediment observation is to clarify the horizontal distribution of bottom sediments in the sea around the Abu Dhabi Island.

(2) Observation Location

The observation locations are shown in Fig. 3.7.1. 20 locations were selected so that the distribution of bottom sediment in the sea around the Abu Dhabi Island could be ascertained generally.

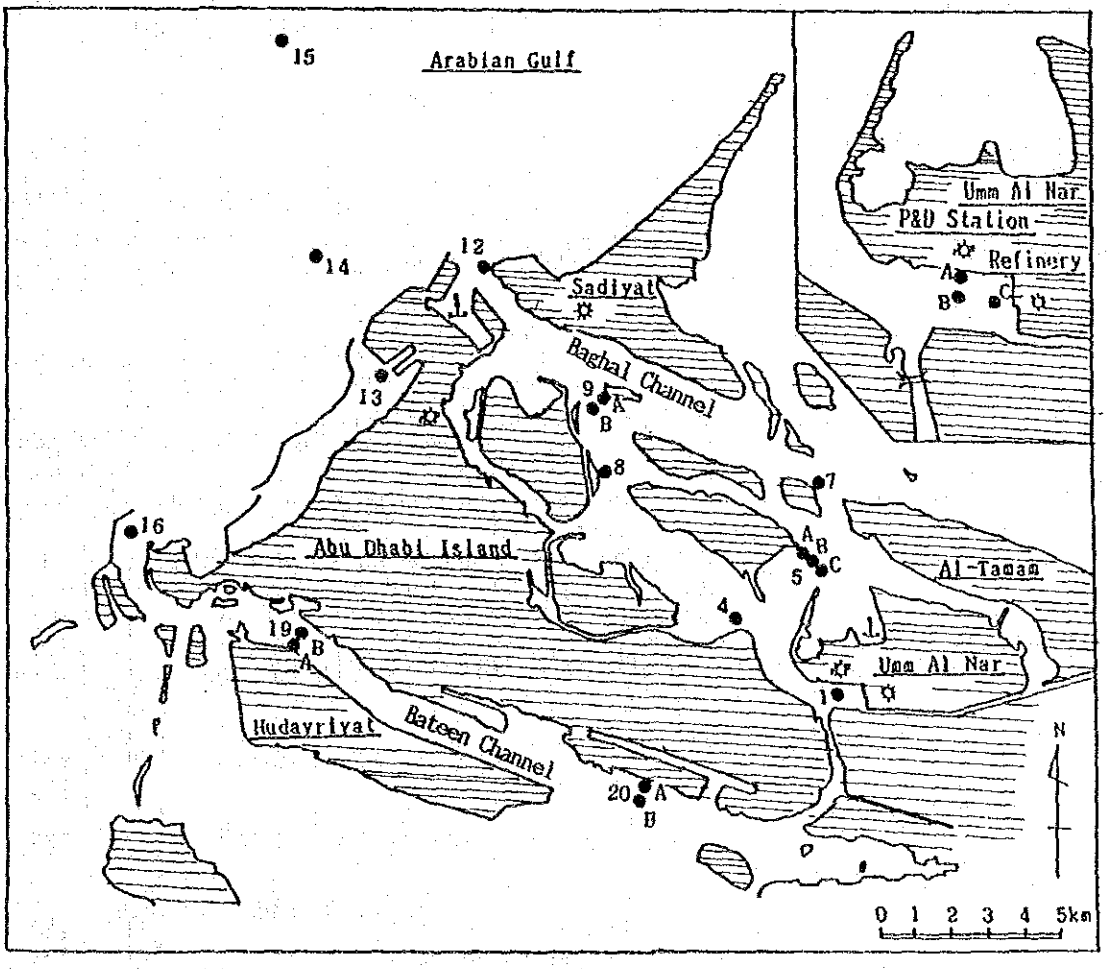



Fig. 3.7.1: Observation Location of Bottom Sediment

(3) Duration of Observation

The duration of sampling is as follows :

1) Second Field Survey

* October, 1988

2) Third Field Survey

* February, 1989

(4) Method of Observation

The bottom sediments were sampled with a bottom sampler of the Smith-McIntyre type (sampling area : 0.05 $m^2$) and were examined in Japan by the method as shown in Fig. 3.7.1.

(5) Results

1) Second Field Survey

The results of bottom sediments tests are shown in Tables 3.7.2(1) to (3). The basic statistical table of bottom sediments is as shown in Table 3.7.3.

Table 3.7.1: Analytical Methods of Bottom Sediment

| Parameter | Method | Reference |
|---|---|---|
| Appearance | Visual Inspection | — |
| Color | Comparison with standard soil color note | 9) |
| Grain Size | Meshes and sedimentation test | 10) |
| Specific Gravity | Gravimetric analysis with picnometer | 11) |
| Specific Surface Area | Calculation from size distribution and specific gravity | — |
| Total Organic Carbon | Potassium bichromate titration method | 14) |
| Oil Content (Quantitative) | Infra-red method | 15) |
| Oil Content (Qualitative) | FID Gas Chromatography Method | 16) |
| Mercury | Atomic absorption method | 12) |
| Lead | Atomic absorption method | 12) |
| Cadmium | Atomic absorption method | 12) |
| Chromium | Atomic absorption method | 12) |
| Copper | Atomic absorption method | 12) |
| Zinc | Atomic absorption method | 12) |
| Stannum | Atomic absorption method | 12) |

Table 3.7.2(1): Analysis Results of Bottom Sediment in Second Field Survey (Sampling in October, 1988)

| Site / Parameter | 1-A | 1-B | 1-C | 4 | 5-A | 5-B | 5-C | 7 |
|---|---|---|---|---|---|---|---|---|
| Appearance | Silt | Sand | Silt | Sand | Silt | Sand with Shells | Silt | Sand |
| Color | 10Y5/1 Gray | 7.5Y5/2 Grayish Olive | 10Y5/1 Gray | 10GY4/1 Dark Greenish Gray | 10GY5/1 Greenish Gray | 10GY4/1 Dark Greenish Gray | 10GY5/1 Greenish Gray | 10Y6/2 Olive Gray |
| Size (%) Distribution | | | | | | | | |
| Pebbles | 2.0 | 1.1 | 1.0 | 2.8 | 5.5 | 10.0 | 1.2 | 3.0 |
| Granules | 5.0 | 0.2 | 1.7 | 0.9 | 2.3 | 11.0 | 0.1 | 1.0 |
| V. Coase Sand | 6.0 | 0.2 | 2.3 | 0.3 | 2.2 | 11.0 | 1.2 | 2.0 |
| Coase Sand | 7.0 | 13.5 | 2.0 | 0.5 | 11.0 | 10.0 | 3.0 | 6.0 |
| Medium Sand | 5.5 | 26.5 | 2.5 | 2.5 | 7.5 | 9.3 | 7.7 | 43.0 |
| Fine Sand | 2.5 | 10.5 | 2.0 | 41.5 | 3.5 | 23.7 | 4.8 | 9.0 |
| V. Fine Sand | 11.0 | 9.0 | 16.0 | 20.5 | 7.0 | 9.0 | 5.0 | 7.0 |
| Silt | 61.0 | 39.0 | 72.5 | 12.0 | 61.0 | 6.0 | 77.0 | 23.0 |
| Clay | 0.0 | 0.0 | 0.0 | 19.0 | 0.0 | 10.0 | 0.0 | 6.0 |
| Specific Gravity (-) | 2.71 | 2.70 | 2.71 | 2.70 | 2.72 | 2.74 | 2.74 | 2.70 |
| Specific Surface Area (m²/g) | 0.48 | 0.31 | 0.59 | 0.36 | 0.56 | 0.18 | 0.85 | 0.23 |
| Hg (ppm) | 0.09 | 0.03 | 0.11 | <0.01 | 0.04 | 0.06 | 0.16 | 0.02 |
| Pb (ppm) | 6 | 5 | 8 | 3 | 3 | 2 | 4 | 2 |
| Cd (ppm) | 0.1 | <0.1 | <0.1 | 0.1 | <0.1 | <0.1 | 0.1 | 0.1 |
| Cr (ppm) | 101 | 171 | 62 | 136 | 74 | 104 | 129 | 174 |
| Cu (ppm) | 16 | 10 | 21 | 6 | 11 | 9 | 26 | 6 |
| Zn (ppm) | 23 | 17 | 27 | 12 | 12 | 8 | 18 | 10 |
| Sn (ppm) | <10 | <10 | <10 | <10 | <10 | <10 | <10 | <10 |
| TOC (%) | 0.90 | 0.52 | 1.19 | 0.66 | 1.39 | 0.36 | 1.26 | 0.28 |
| Oil (ppm) | 50 | 39 | 67 | 45 | 46 | 31 | 67 | 17 |
| n-Parafine Peak Ratio (-) | | | | | | | | |
| $C_{14}$ | 0.1 | 0.1 | 0.2 | - | - | 0.1 | 0.2 | 0.4 |
| $C_{15}$ | 0.2 | 0.2 | 0.2 | 0.1 | 0.4 | 0.1 | 0.3 | 0.2 |
| $C_{16}$ | 0.1 | 0.1 | - | - | 0.1 | 0.1 | - | 0.2 |
| $C_{17}$ | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| $C_{18}$ | 3.0 | 2.1 | 2.5 | 0.1 | 0.5 | 0.3 | 0.5 | 0.6 |
| $C_{19}$ | 0.7 | 0.5 | 0.5 | 0.1 | 0.3 | 0.3 | 0.5 | 0.4 |
| $C_{20}$ | 0.5 | 0.4 | 0.5 | 0.1 | 0.1 | 0.1 | 1.3 | 0.2 |
| $C_{21}$ | 0.5 | 0.4 | 0.3 | 0.2 | 0.2 | 0.3 | 0.3 | 0.2 |
| $C_{22}$ | 0.2 | 0.1 | 0.2 | - | - | - | 0.5 | - |
| $C_{23}$ | 0.2 | 0.1 | 0.2 | - | 0.1 | - | 0.2 | - |
| $C_{24}$ | 0.3 | 0.1 | 0.2 | - | - | - | 0.3 | - |
| $C_{25}$ | - | - | - | - | - | - | - | - |
| $C_{26}$ | 0.6 | 0.2 | 0.3 | 0.1 | 0.1 | - | 0.7 | 0.2 |
| $C_{27}$ | 0.9 | 0.5 | 0.5 | 0.2 | 0.6 | 0.2 | 0.7 | 0.4 |
| $C_{28}$ | 0.8 | 0.9 | 1.0 | 0.2 | 0.5 | 0.2 | 0.8 | 0.6 |
| $C_{29}$ | 0.7 | 0.4 | 0.5 | 0.1 | 0.6 | 0.2 | 0.8 | 0.4 |
| $C_{30}$ | 1.9 | 4.1 | 1.8 | 1.1 | 2.2 | 10.8 | 5.7 | 2.2 |
| $C_{31}$ | 0.5 | 1.0 | 1.2 | 0.7 | 1.4 | 3.8 | 4.0 | 0.6 |
| $C_{32}$ | 1.5 | 1.5 | 1.3 | 1.3 | 1.9 | 4.4 | 6.5 | 1.2 |

Notes: Size Classification

| | Particle Size (mm) |
|---|---|
| Pebbles | 4~64 |
| Granules | 2~4 |
| Very Coase Sand | 1~2 |
| Coase Sand | 1/2~1 |
| Medium Sand | 1/4~1/2 |
| Fine Sand | 1/8~1/4 |
| Very Fine Sand | 1/16~1/8 |
| Silt | 1/256~1/16 |
| Clay | <1/256 |

Remarks: Dry Base

Table 3.7.2(2): Analysis Results of Bottom Sediment in Second Field Survey (Sampling in October, 1988)

| Site / Parameter | 8 | 9-A | 9-B | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|
| Appearance | Sand | Sand | Sand | Sand with Shells | Sand | Sand | Sand | Sand |
| Color | 10GY4/1 Dark Greenish Gray | 10GY4/1 Dark Greenish Gray | 5Y5/3 Grayish Olive | 5Y7/3 Light Yellow | 10GY5/1 Greenish Gray | 10GY4/1 Dark Greenish Gray | 5YG/4 Olive Yellow | 5Y6/2 Grayish Olive |
| Size (%) Distribution | | | | | | | | |
| Pebbles | 4.6 | 4.0 | 7.0 | 6.5 | 3.0 | 2.5 | 2.0 | 3.0 |
| Granules | 3.3 | 7.0 | 9.0 | 3.0 | 2.0 | 1.7 | 1.0 | 3.8 |
| V. Coase Sand | 8.1 | 6.0 | 16.0 | 8.5 | 10.9 | 2.3 | 6.0 | 14.7 |
| Coase Sand | 56.0 | 16.0 | 25.0 | 33.5 | 31.1 | 41.0 | 31.0 | 48.5 |
| Medium Sand | 15.0 | 49.8 | 33.3 | 38.5 | 31.5 | 17.5 | 37.5 | 26.4 |
| Fine Sand | 1.0 | 4.2 | 5.2 | 7.5 | 2.2 | 4.0 | 15.5 | 1.0 |
| V. Fine Sand | 2.5 | 3.8 | 3.0 | 2.3 | 2.0 | 6.0 | 5.5 | 2.6 |
| Silt | 9.5 | 1.8 | 1.5 | 0.2 | 4.1 | 25.0 | 1.5 | 0.0 |
| Clay | 0.0 | 7.4 | 0.0 | 0.0 | 7.2 | 0.0 | 0.0 | 0.0 |
| Specific Gravity (-) | 2.72 | 2.74 | 2.71 | 2.81 | 2.78 | 2.74 | 2.76 | 2.78 |
| Specific Surface Area (m²/g) | 0.16 | 0.17 | 0.0053 | 0.0048 | 0.17 | 0.31 | 0.0071 | 0.0074 |
| Hg (ppm) | <0.01 | 0.02 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Pb (ppm) | 2 | 2 | 2 | 1 | 3 | 3 | 2 | 1 |
| Cd (ppm) | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| Cr (ppm) | 140 | 100 | 89 | 51 | 56 | 79 | 70 | 37 |
| Cu (ppm) | 4 | 3 | 2 | 1 | 12 | 5 | 1 | <1 |
| Zn (ppm) | 8 | 5 | 4 | 2 | 7 | 9 | 2 | 1 |
| Sn (ppm) | <10 | <10 | <10 | <10 | <10 | <10 | <10 | <10 |
| TOC (%) | 0.40 | 0.29 | 0.12 | 0.17 | 0.43 | 0.60 | 0.43 | 0.17 |
| Oil (ppm) | 24 | 36 | 8 | 8 | 81 | 83 | 35 | 12 |
| n-Paraffine Peak Ratio (-) | | | | | | | | |
| $C_{14}$ | 0.1 | 0.1 | 1.2 | 0.9 | - | 0.1 | - | 0.6 |
| $C_{15}$ | 0.2 | 0.2 | 0.8 | 0.6 | 0.1 | 0.2 | 0.2 | 0.5 |
| $C_{16}$ | 0.1 | 0.1 | 0.3 | 0.4 | 0.1 | - | - | 0.4 |
| $C_{17}$ | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| $C_{18}$ | 0.2 | 0.1 | 0.3 | 0.3 | - | 0.2 | 0.1 | 0.4 |
| $C_{19}$ | 0.2 | 0.2 | 0.3 | 1.1 | - | 0.2 | 0.1 | 1.1 |
| $C_{20}$ | 1.5 | 2.5 | 0.2 | - | - | 1.1 | 1.4 | 0.8 |
| $C_{21}$ | 0.2 | 0.2 | 0.3 | 0.4 | 0.2 | 0.4 | 0.3 | 0.4 |
| $C_{22}$ | 0.2 | 0.2 | - | 0.1 | 0.1 | 0.1 | - | 0.3 |
| $C_{23}$ | 0.1 | 0.3 | 0.2 | 0.3 | 0.1 | - | 0.1 | 0.4 |
| $C_{24}$ | - | - | 0.2 | 0.4 | - | 0.1 | 0.1 | 0.8 |
| $C_{25}$ | - | - | - | - | - | - | - | - |
| $C_{26}$ | 0.2 | 0.3 | 0.2 | 1.4 | 0.2 | 0.2 | 0.4 | 2.5 |
| $C_{27}$ | 0.5 | 0.7 | 0.3 | 1.0 | 0.1 | 0.2 | 0.9 | 1.3 |
| $C_{28}$ | 0.3 | 0.3 | 0.3 | 0.4 | 0.1 | 0.3 | 0.2 | 0.8 |
| $C_{29}$ | 0.5 | 0.5 | 0.5 | 0.5 | 0.1 | 0.2 | 0.9 | 1.6 |
| $C_{30}$ | 1.7 | 2.2 | 4.2 | 1.1 | 0.4 | 1.4 | 0.6 | 1.1 |
| $C_{31}$ | 1.4 | 1.6 | 0.5 | 0.4 | 0.7 | 1.2 | 0.2 | 0.4 |
| $C_{32}$ | 2.1 | 2.3 | 1.5 | 1.1 | 1.3 | 1.5 | 0.9 | 1.3 |

Notes: Size Classification

| | Particle Size (mm) |
|---|---|
| Pebbles | 4~64 |
| Granules | 2~4 |
| Very Coase Sand | 1~2 |
| Coase Sand | 1/2~1 |
| Medium Sand | 1/4~1/2 |
| Fine Sand | 1/8~1/4 |
| Very Fine Sand | 1/16~1/8 |
| Silt | 1/256~1/16 |
| Clay | <1/256 |

Remarks: Dry Base

Table 3.7.2(3): Analysis Results of Bottom Sediment in Second Field Survey (Sampling in October, 1988)

| Site / Parameter | 19-A | 19-B | 20-A | 20-B | | | | |
|---|---|---|---|---|---|---|---|---|
| Appearance | Sand | Sand | Sand | Sand with Shells | | | | |
| Color | 10BG4/1 Dark Bluish Gray | 10BG5/1 Bluish Gray | 10BG6/1 Bluish Gray | 10BG5/1 Bluish Gray | | | | |
| Size (%) Distribution | | | | | | | | |
| Pebbles | 1.1 | 3.0 | 9.0 | 1.2 | | | | |
| Granules | 0.6 | 12.2 | 6.0 | 0.3 | | | | |
| V. Coase Sand | 2.3 | 42.8 | 7.0 | 0.5 | | | | |
| Coase Sand | 44.0 | 34.0 | 9.0 | 1.0 | | | | |
| Modium Sand | 19.1 | 4.9 | 29.0 | 39.9 | | | | |
| Fine Sand | 1.9 | 2.1 | 20.5 | 4.6 | | | | |
| V. Fine Sand | 4.0 | 1.0 | 7.5 | 6.5 | | | | |
| Silt | 27.0 | 0.0 | 4.8 | 24.0 | | | | |
| Clay | 0.0 | 0.0 | 7.2 | 22.0 | | | | |
| Specific Gravity (-) | 2.71 | 2.79 | 2.78 | 2.72 | | | | |
| Specific Surface Area (m²/g) | 0.35 | 0.0087 | 0.14 | 0.53 | | | | |
| Hg (ppm) | <0.01 | <0.01 | <0.01 | <0.01 | | | | |
| Pb (ppm) | 2 | 1 | 1 | 3 | | | | |
| Cd (ppm) | <0.1 | <0.1 | <0.1 | <0.1 | | | | |
| Cr (ppm) | 139 | 29 | 69 | 253 | | | | |
| Cu (ppm) | 4 | 1 | 2 | 6 | | | | |
| Zn (ppm) | 11 | 2 | 2 | 13 | | | | |
| Sn (ppm) | <10 | <10 | <10 | <10 | | | | |
| TOC (%) | 0.45 | 0.17 | 0.49 | 0.58 | | | | |
| Oil (ppm) | 28 | 2 | 28 | 30 | | | | |
| n-Parafine Peak Ratio (-) | | | | | | | | |
| $C_{14}$ | 0.1 | 1.2 | 0.2 | - | | | | |
| $C_{15}$ | 0.4 | 0.6 | 0.5 | 0.1 | | | | |
| $C_{16}$ | 0.1 | 0.4 | - | - | | | | |
| $C_{17}$ | 1.0 | 1.0 | 1.0 | 1.0 | | | | |
| $C_{18}$ | 0.3 | 0.4 | 0.4 | 0.7 | | | | |
| $C_{19}$ | 0.3 | 0.4 | 0.5 | 0.3 | | | | |
| $C_{20}$ | 0.1 | 0.8 | 2.4 | 0.1 | | | | |
| $C_{21}$ | 1.0 | 0.5 | 0.3 | 0.4 | | | | |
| $C_{22}$ | 0.1 | 0.2 | 0.3 | 0.1 | | | | |
| $C_{23}$ | 0.1 | 0.2 | 0.2 | 0.1 | | | | |
| $C_{24}$ | 0.1 | 0.4 | 0.2 | - | | | | |
| $C_{25}$ | - | - | - | - | | | | |
| $C_{26}$ | 0.1 | 0.7 | 0.3 | 0.1 | | | | |
| $C_{27}$ | 0.3 | 1.5 | 0.7 | 0.4 | | | | |
| $C_{28}$ | 0.3 | 0.5 | 0.3 | 0.3 | | | | |
| $C_{29}$ | 0.2 | 1.6 | 1.4 | 0.4 | | | | |
| $C_{30}$ | 3.6 | 1.0 | 7.8 | 2.7 | | | | |
| $C_{31}$ | 2.5 | 1.1 | 1.4 | 0.7 | | | | |
| $C_{32}$ | 5.0 | 2.6 | 2.3 | 2.1 | | | | |

Notes: Size Classification

| | Particle Size (mm) |
|---|---|
| Pebbles | 4~64 |
| Granules | 2~4 |
| Very Coase Sand | 1~2 |
| Coase Sand | 1/2~1 |
| Modium Sand | 1/4~1/2 |
| Fine Sand | 1/8~1/4 |
| Very Fine Sand | 1/16~1/8 |
| Silt | 1/256~1/16 |
| Clay | <1/256 |

Remarks: Dry Base

Table 3.7.3: Basic Statistical Table of Bottom Sediment in Second Field Survey (Sampling in October, 1988)

| Parameter \ Item / Unit | Sample Number | Max. | Min. | Ave. | S.D. |
|---|---|---|---|---|---|
| Specific Gravity — | 20 | 2.81 | 2.70 | 2.74 | 0.03 |
| Specific Surface Area $m^2/g$ | 20 | 0.85 | 0.0048 | 0.27 | 0.24 |
| Hg ppm | 20 | 0.16 | <0.01 | 0.03 | 0.04 |
| Pb ppm | 20 | 8 | 1 | 3 | 2 |
| Cd ppm | 20 | 0.1 | <0.1 | 0.1 | 0.0 |
| Cr ppm | 20 | 253 | 29 | 103 | 55 |
| Cu ppm | 20 | 26 | <1 | 8 | 7 |
| Zn ppm | 20 | 27 | 1 | 10 | 7 |
| Sn ppm | 20 | <10 | <10 | <10 | — |
| TOC % | 20 | 1.39 | 0.12 | 0.54 | 0.37 |
| Oil ppm | 20 | 83 | 2 | 37 | 24 |

(a) Appearance and Color

During sampling sediments, observation was conducted on the appearance and color of bottom sediments to identify their basic properties. Colors were compared with those shown in the color charts of the reference soil color manual so that an objective judgment could be made.

Bottom sediments around the Abu Dhabi Island were sandy or silty, and some sites showed sandy sediments including shells. Colors were light yellow at Site 12 and olive yellow at Site 15. At the other sites, the sediments presented grayish colors such as greenish gray, bluish gray and olive gray.

(b) Particle Size Composition

Particles in the sediments are classified per particle diameter, and the ratio of their composition is usually indicated in weight percentage.

In both Baghal Channel and Bateen Channel on both sides of the Abu Dhabi Island, the sediments found on both sides of the channel showed a fine particle size as compared with those in the center of the channel. Also, in the part near the sea water intake facilities of Umm Al Nar Station, silty sediments were accumulated, which are considered attributable to slow tidal currents.

(c) Specific Gravity

The specific gravity of coastal sediments is usually about 2.7, but it increases when the ratio of heavy minerals such as iron is large.

The specific gravity was in the range of 2.70 to 2.81, and no distribution tendency was recognized among the sites.

(d) Specific Surface Area

The specific surface area means the surface area of sediment particle per unit weight. Assuming that the sediment particle is a true ball, the specific surface area was calculated from the measured results of particle size composition and specific gravity.

At Site 9-B, Site 12, Site 15, Site 16 and Site 19-B, coarse particles were recognized as they were washed away by strong tidal currents and the specific surface area was 0.0048 to 0.0087 $m^2/g$, which was about 1/100 of that at the other sites (0.14 to 0.59 $m^2/g$).

(e) Mercury (Hg)

It is said that the amount of mercury which exists in the crust is 0.08 ppm and almost the same level of mercury is contained in both granite and basalt.

In sedimentary rocks, the amount of mercury contained in shale is about 0.4 ppm and that in sandstone is about 0.03 ppm. The amount of mercury which exists in soil is about 0.03 to 0.3 ppm.

Mercury around the Abu Dhabi Island was in the range of less than 0.01 to 0.16 ppm and no mercury contamination was recognized.

(f) Lead (Pb)

It is said that the amount of lead which exists in the crust is 12.5 ppm, 20 ppm of lead is contained in granite and 4 ppm in basalt. In sedimentary rocks, the amount of lead contained in shale is about 20 ppm and about 7 ppm in sandstone, in soil 5 to 500 ppm, or 10 ppm on the average.

At Site 1-A, Site 1-B and Site 1-C near the sea water intake facilities of Umm Al Nar Station, where many silty sediments were found, the amount of lead indicated a little higher value (5 to 8 ppm), but was in the range of 1 to 8 ppm at all the sites. No lead contamination was recognized.

(g) Cadmium (Cd)

It is said that the amount of cadmium which exists in the crust is 0.2 ppm and almost the same level of cadmium is contained in both granite and basalt. In sedimentary rocks, the amount of cadmium contained in shale is 0.3 ppm and less in sandstone. It is estimated that the average amount of cadmium contained in soil is about 0.1 ppm, though it varies largely with regions.

Cadmium around the Abu Dhabi Island was 0.1 ppm or less, and no cadmium contamination was recognized.

(h) Chromium (Cr)

It is said that the amount of chromium which exists in the crust is 100 ppm, and chromium is considerably maldistributed in granite (4 ppm) and in basalt (200 ppm). In sedimentary rocks, the amount of chromium contained in shale is about 90 ppm and 35 ppm in sandstone. The amount of chromium contained in soil is about 5 to 1,000 ppm, and 200 ppm on the average. The chromium around the Abu Dhabi Island was in the range of 29 to 253 ppm, and no chromium contamination was recognized.

(i) Copper (Cu)

The average amount of copper which exists in the crust is 55 ppm, 10 ppm is contained in granite, and 100 ppm in basalt. In sedimentary rocks, the amount of copper contained in shale is about 45 ppm and several ppm in sandstone. Soil contains 2 to 100 ppm of copper, and 20 ppm on the average.

The copper around the Abu Dhabi Island was in the range of less than 1 to 26 ppm. At Site 1-A, Site 1-B, Site 1-C near the sea water intake facilities of Umm Al Nar Station, and Site 5-A and Site 5-C near the brine discharge facilities of Umm Al Nar Station and Site 12, copper of more

than 10 ppm was detected, thus showing a little higher value as compared with the other sites, probably due to the corrosion of copper tubes.

(j) Zinc (Zn)

The amount of zinc which exists in the crust is 70 ppm, 40 ppm is contained in granite and 100 ppm in basalt. In sedimentary rocks, it is said that the amount of zinc contained in shale is about 95 ppm, about 16 ppm in sandstone. Soil contains 10 to 300 ppm of zinc, and 50 ppm on the average.

The zinc around the Abu Dhabi Island was in the range of 1 to 27 ppm. At Site 1-A and Site 1-B near the sea water intake facilities of Umm Al Nar Station and Site 5-C near the brine discharge facilities of Umm Al Nar Station, slightly higher values were detected as compared with the other sites.

(k) Tin (Sn)

The amount of tin which exists in the crust is 2 ppm, 3.5 ppm is contained in granite and 1 ppm in basalt. In sedimentary rocks, it is said that the amount of tin contained in shale is about 6 ppm and 0.5 ppm in sandstone. Soil contains 1 to 200 ppm of tin, and 4 ppm on the average.

The tin was less than 10 ppm at all the sites, and no tin contamination was recognized.

(l) Total Organic Carbon (TOC)

TOC refers to carbon in organic matter found in sediments, and it is referred to as an index of organic contamination in bottom sediments. The TOC value increases owing to oil contamination as well.

The TOC around the Abu Dhabi Island was in the range of 0.12 to 1.39%. At Site 1-A, Site 1-B, Site 5-A and Site 5-C where the ratio of sediments below the silt portion accounted for 50% or more, TOC of 0.90 to 1.39% was detected, indicating a little higher value than the other sites.

(m) Oil Content (Oil)

The oil content is a mixture of various oily substances including petroleum base hydrocarbon, animal and vegetable oils and fats, fatty acid, grease, etc.

The oil content around the Abu Dhabi Island was in the range of 2 to 83 ppm. A high oil content was detected at Site 13 (81 ppm) and Site 14 (83 ppm). Also, even at sites around Umm Al Nar Station where many silty sediments exist, a little higher value (about 50 ppm) was detected.

FID gas chromatographic analysis was conducted to determine the properties of oil extracted from sediments. As a result, the peak of the carbon numbers from $C_{14}$ to $C_{32}$ were detected, and with the peaks of $C_{17}$ assumed to be 1.0, the ratio with other peaks were obtained. At each site of, $C_{30}$, $C_{31}$ and $C_{32}$ indicated high values.

2) Third Field Survey

The results of the bottom sediment tests are tabulated in Tables 3.7.4(1) to 3.7.4(3). The basic statistical table on the bottom sediments is shown in Table 3.7.5.

(a) Appearance and Color

Bottom sediments around the Abu Dhabi Island were generally sandy or silty. Some sites showed sandy sediments containing shells.

Colors were olive yellow at Site 9-B, grayish white at Site 12, deep yellow at Site 16, light yellow at Site 19-A. The other sites showed grayish colors such as greenish gray, bluish gray, olive gray, etc.

(b) Particle Size Composition

In both Baghal Channel and Bateen Channel, a fine particle size distribution was recognized on both sides of the channel in the same way as the second field survey. Also, at Site 1-A, Site 1-B and Site 1-C near the sea water intake facilities of Umm Al Nar Station where the tidal currents are slow, the ratio of bottom sediments below the silt portion accounted for 80 to 90%.

The tendency of particle size distribution in the third field survey was similar to that in the second field survey on the whole. At Site 14, however, the ratio of sediments below the silt portion was 0% in the third field survey while that in the second field survey was 32.5% .

(c) Specific Gravity

The specific gravity around the Abu Dhabi Island was in the range of 2.75 to 2.85 and no distribution tendency among the sites was recognized.

(d) Specific Surface Area

In the same way as the second field survey, particles were found to have been washed away, and to be coarse at sites where the velocity of the stream is fast. At Site 9-B, Site 12, Site 14, Site 15 and Site 16, the specific surface area was in the range of 0.0047 to 0.0078 $m^2/g$, which was extremely small as compared with the other sites (0.063 to 0.82 $m^2/g$).

(e) Mercury (Hg)

Mercury of 0.01 to 0.07 ppm was detected at Site 4, Site 8, Site 9-B and Site 20-A where it was less than 0.01 ppm in the second field survey. At all the sites, however, mercury was in the range of 0.01 to 0.19 ppm, and no mercury contamination was recognized.

Table 3.7.4(1): Analysis Results of Bottom Sediment in Third Field Survey (Sampling in February, 1989)

| Site / Parameter | 1-A | 1-B | 1-C | 4 | 5-A | 5-B | 5-C | 7 |
|---|---|---|---|---|---|---|---|---|
| Appearance | Silt | Sand | Silt | Silt | Silt | Sand with Shells | Silt | Sand |
| Color | 7.5Y6/2 Grayish Olive | 7.5Y5/2 Grayish Olive | 10GY5/1 Greenish Gray | 10GY6/1 Greenishen-Gray | 10GY5/1 Greenish Gray | 10Y6/2 Olive Gray | 10GY5/1 Greenish Gray | 10Y5/1 Gray |
| Size (%) Distribution | | | | | | | | |
| Pebbles | 0.5 | 0 | 0 | 2 | 4 | 11.5 | 0 | 13 |
| Granules | 0 | 0 | 0 | 1 | 4 | 13.5 | 0 | 3.5 |
| V. Coase Sand | 0.5 | 0.5 | 0 | 1 | 1 | 11.5 | 0.5 | 13.5 |
| Coase Sand | 0.5 | 0 | 0 | 1.5 | 1.5 | 9.5 | 0.5 | 21.5 |
| Medium Sand | 1.5 | 0.5 | 0.5 | 2.5 | 0.5 | 12.5 | 0.5 | 22 |
| Fine Sand | 7 | 6 | 1.5 | 5.5 | 19 | 20 | 4.5 | 9 |
| V. Fine Sand | 18.5 | 18.5 | 5 | 11 | 17 | 6.5 | 16 | 7 |
| Silt | 33.5 | 36.5 | 49 | 38.5 | 26 | 8.5 | 39 | 5 |
| Clay | 38 | 36 | 45 | 37 | 27 | 6.5 | 39 | 5.5 |
| Specific Gravity (−) | 2.77 | 2.77 | 2.79 | 2.80 | 2.77 | 2.79 | 2.77 | 2.79 |
| Specific Surface Area ($m^2/g$) | 0.72 | 0.60 | 0.82 | 0.71 | 0.51 | 0.13 | 0.74 | 0.11 |
| Hg (ppm) | 0.11 | 0.14 | 0.19 | 0.02 | 0.14 | 0.09 | 0.25 | 0.06 |
| Pb (ppm) | 4 | 4 | 6 | 2 | 2 | 2 | 3 | 1 |
| Cd (ppm) | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| Cr (ppm) | 111 | 109 | 60 | 48 | 116 | 96 | 76 | 43 |
| Cu (ppm) | 13 | 14 | 18 | 8 | 11 | 7 | 23 | 3 |
| Zn (ppm) | 24 | 23 | 26 | 13 | 13 | 8 | 18 | 5 |
| Sn (ppm) | <10 | <10 | <10 | <10 | <10 | <10 | <10 | <10 |
| TOC (%) | 0.74 | 0.68 | 1.07 | 1.2 | 0.76 | 0.36 | 1.32 | 0.39 |
| Oil (ppm) | 40 | 36 | 58 | 32 | 24 | 19 | 37 | 36 |
| n-Paraffine Peak Ratio (−) | | | | | | | | |
| C14 | 0.5 | 0.3 | 0.3 | 0.2 | 0.2 | 0.0 | 0.1 | 0.0 |
| C15 | 0.7 | 0.3 | 0.2 | 0.4 | 0.8 | 0.0 | 0.1 | 0.0 |
| C16 | 0.2 | 0.3 | 0.3 | 0.2 | 0.1 | 0.2 | 0.2 | 0.0 |
| C17 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| C18 | 1.5 | 1.6 | 2.3 | 0.4 | 0.9 | 0.8 | 0.7 | 0.3 |
| C19 | 0.2 | 0.7 | 0.3 | 0.3 | 0.4 | 0.8 | 0.5 | 0.7 |
| C20 | 0.2 | 0.3 | 0.3 | 0.1 | 0.3 | 0.6 | 0.6 | 0.3 |
| C21 | 0.4 | 0.5 | 0.3 | 0.4 | 0.5 | 1.0 | 0.5 | 0.0 |
| C22 | 0.4 | 0.4 | 0.3 | 0.1 | 0.3 | 1.0 | 0.2 | 0.0 |
| C23 | 0.3 | 0.5 | 0.3 | 0.2 | 0.4 | 1.4 | 0.6 | 0.2 |
| C24 | 0.5 | 0.6 | 0.5 | 0.2 | 0.5 | 1.8 | 0.4 | 0.2 |
| C25 | 0.9 | 1.1 | 0.8 | 0.8 | 1.1 | 4.6 | 1.5 | 0.8 |
| C26 | 0.4 | 0.5 | 0.5 | 0.4 | 0.4 | 1.2 | 0.5 | 0.2 |
| C27 | 0.2 | 0.3 | 0.5 | 0.3 | 0.5 | 0.8 | 0.6 | 0.0 |
| C28 | 0.4 | 0.7 | 0.7 | 0.4 | 0.4 | 0.8 | 0.4 | 0.2 |
| C29 | 0.2 | 0.3 | 0.2 | 0.2 | 0.4 | 0.4 | 0.5 | 0.0 |
| C30 | 0.7 | 0.9 | 1.2 | 2.2 | 2.4 | 16.6 | 1.7 | 18.8 |
| C31 | 0.4 | 0.9 | 0.7 | 0.6 | 0.4 | 1.6 | 1.2 | 3.0 |
| C32 | 0.8 | 1.0 | 0.8 | 1.7 | 1.9 | 5.8 | 3.1 | 9.2 |

Notes: Size Classification / Particle Size (mm)

| | |
|---|---|
| Pebbles | 4~64 |
| Granules | 2~4 |
| Very Coase Sand | 1~2 |
| Coase Sand | 1/2~1 |
| Medium Sand | 1/4~1/2 |
| Fine Sand | 1/8~1/4 |
| Very Fine Sand | 1/16~1/8 |
| Silt | 1/256~1/16 |
| Clay | <1/256 |

Remarks: Dry Base

Table 3.7.4(2): Analysis Results of Bottom Sediment in Third Field Survey (Sampling in February, 1989)

| Site / Parameter | 8 | 9-A | 9-B | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|
| Appearance | Sand | Silt | Sand | Sand | Sand | Sand | Sand | Sand |
| Color | 10GY5/1 Greenishen-Gray | 10GY5/1 Greenishen-Gray | 5Y6/3 Olive Yellow | 5Y7/2 Light Gray | 7.5Y5/1 Gray | 10Y5/1 Gray | 7.5GY5/1 Greenish Gray | 5Y8/3 Pale Yellow |
| Size (%) Distribution | | | | | | | | |
| Pebbles | 1.5 | 0.5 | 0.5 | 0.5 | 1 | 5.5 | 0.5 | 0.5 |
| Granules | 3.5 | 0 | 2 | 2 | 2 | 3 | 1.5 | 0.5 |
| V. Coase Sand | 3 | 1.5 | 6 | 8 | 4 | 11 | 5.5 | 9 |
| Coase Sand | 4.5 | 2.5 | 23.5 | 23.5 | 11 | 35.5 | 12.5 | 48 |
| Medium Sand | 9 | 8 | 48 | 48 | 40 | 31 | 57 | 35.5 |
| Fine Sand | 1.5 | 33 | 13.5 | 13.5 | 25.5 | 10 | 16.5 | 4 |
| V. Fine Sand | 19.5 | 20.5 | 4.5 | 4.5 | 4.5 | 4 | 6.5 | 2.5 |
| Silt | 28 | 18 | 0 | 0 | 6.5 | 0 | 0 | 0 |
| Clay | 29.5 | 16 | 0 | 0 | 5.5 | 0 | 0 | 0 |
| Specific Gravity (-) | 2.78 | 2.76 | 2.80 | 2.85 | 2.83 | 2.82 | 2.79 | 2.83 |
| Specific Surface Area (m²/g) | 0.54 | 0.29 | 0.0066 | 0.0062 | 0.12 | 0.0052 | 0.0078 | 0.0047 |
| Hg (ppm) | 0.07 | 0.08 | 0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Pb (ppm) | 4 | 2 | 1 | <1 | 1 | 1 | 1 | <1 |
| Cd (ppm) | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| Cr (ppm) | 63 | 100 | 46 | 31 | 32 | 50 | 40 | 35 |
| Cu (ppm) | 12 | 7 | 2 | 1 | 8 | 1 | <1 | 1 |
| Zn (ppm) | 20 | 14 | 4 | 2 | 5 | 3 | 2 | <1 |
| Sn (ppm) | <10 | <10 | <10 | <10 | <10 | <10 | <10 | <10 |
| TOC (%) | 1.25 | 0.59 | 0.16 | 0.13 | 0.48 | 0.22 | 0.26 | 0.17 |
| Oil (ppm) | 72 | 26 | 11 | 5 | 44 | 8 | 9 | 6 |
| n-Paraffin Peak Ratio (-) | | | | | | | | |
| C14 | 0.1 | 0.3 | 0.3 | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 |
| C15 | 0.1 | 0.1 | 5.3 | 9.0 | 0.1 | 0.0 | 1.0 | 1.5 |
| C16 | 0.1 | 0.2 | 0.7 | 0.0 | 0.2 | 0.0 | 0.2 | 0.5 |
| C17 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| C18 | 0.2 | 0.4 | 1.3 | 1.0 | 0.3 | 0.2 | 0.4 | 1.5 |
| C19 | 0.2 | 0.4 | 2.3 | 6.5 | 0.3 | 0.8 | 1.2 | 4.5 |
| C20 | 0.2 | 0.5 | 7.0 | 9.5 | 0.2 | 1.5 | 3.4 | 5.5 |
| C21 | 0.4 | 0.4 | 3.0 | 4.5 | 0.4 | 1.2 | 1.0 | 2.0 |
| C22 | 0.1 | 0.3 | 6.3 | 8.5 | 0.3 | 1.8 | 1.6 | 4.0 |
| C23 | 0.3 | 0.6 | 6.7 | 10.0 | 0.4 | 2.3 | 2.0 | 4.5 |
| C24 | 0.3 | 0.4 | 13.0 | 14.0 | 0.6 | 3.3 | 3.0 | 8.5 |
| C25 | 0.8 | 1.3 | 19.0 | 31.5 | 1.1 | 7.7 | 8.8 | 23.0 |
| C26 | 0.2 | 0.3 | 5.0 | 7.0 | 0.3 | 1.8 | 1.4 | 3.5 |
| C27 | 0.5 | 0.5 | 4.0 | 5.5 | 0.3 | 1.0 | 1.4 | 3.0 |
| C28 | 0.3 | 0.3 | 5.7 | 6.0 | 0.3 | 1.0 | 2.0 | 6.0 |
| C29 | 0.3 | 0.5 | 1.7 | 3.0 | 0.1 | 0.5 | 0.6 | 1.0 |
| C30 | 1.2 | 1.5 | 2.7 | 3.0 | 1.3 | 2.3 | 2.2 | 1.5 |
| C31 | 0.9 | 1.6 | 0.3 | 0.0 | 1.0 | 0.7 | 0.4 | 0.0 |
| C32 | 2.5 | 3.5 | 2.3 | 2.0 | 1.6 | 1.0 | 1.2 | 0.0 |

Notes: Size Classification

| | Particle Size (mm) |
|---|---|
| Pebbles | 4~64 |
| Granules | 2~4 |
| Very Coase Sand | 1~2 |
| Coase Sand | 1/2~1 |
| Medium Sand | 1/4~1/2 |
| Fine Sand | 1/8~1/4 |
| Very Fine Sand | 1/16~1/8 |
| Silt | 1/256~1/16 |
| Clay | <1/256 |

Remarks: Dry Base

Table 3.7.4(3): Analysis Results of Bottom Sediment in Third Field Survey (Sampling in February, 1989)

| Site / Parameter | 19-A | 19-B | 20-A | 20-B | | | | |
|---|---|---|---|---|---|---|---|---|
| Appearance | Silt | Sand | Silt | Sand | | | | |
| Color | 5Y7/3 Light Yellow | 10Y7/1 Light Gray | 10GY5/1 Greenish Gray | 10GY5/1 Greenish Gray | | | | |
| Size (%) Distribution | | | | | | | | |
| Pebbles | 0 | 1 | 1 | 1 | | | | |
| Granules | 0 | 1 | 0 | 1.5 | | | | |
| V. Coase Sand | 0.5 | 2 | 0 | 3 | | | | |
| Coase Sand | 0.5 | 4 | 0.5 | 10 | | | | |
| Medium Sand | 28 | 18.5 | 4.5 | 30 | | | | |
| Fine Sand | 60 | 13.5 | 39.5 | 34 | | | | |
| V. Fine Sand | 3 | 12 | 22 | 8.5 | | | | |
| Silt | 5 | 30 | 13 | 5 | | | | |
| Clay | 3 | 18 | 19.5 | 7 | | | | |
| Specific Gravity (-) | 2.79 | 2.75 | 2.79 | 2.78 | | | | |
| Specific Surface Area (m²/g) | 0.06 | 0.34 | 0.39 | 0.14 | | | | |
| Hg (ppm) | <0.01 | <0.01 | 0.01 | <0.01 | | | | |
| Pb (ppm) | <1 | 2 | 2 | 1 | | | | |
| Cd (ppm) | <0.1 | <0.1 | <0.1 | <0.1 | | | | |
| Cr (ppm) | 60 | 66 | 106 | 107 | | | | |
| Cu (ppm) | 2 | 4 | 4 | 3 | | | | |
| Zn (ppm) | 3 | 6 | 9 | 6 | | | | |
| Sn (ppm) | <10 | <10 | <10 | <10 | | | | |
| TOC (%) | 0.2 | 0.43 | 0.66 | 0.24 | | | | |
| Oil (ppm) | 9 | 30 | 14 | 9 | | | | |
| n-Paraffine Peak Ratio (-) | | | | | | | | |
| C14 | 0.4 | 0.8 | 0.5 | 0.4 | | | | |
| C15 | 2.3 | 0.2 | 0.4 | 0.4 | | | | |
| C16 | 0.6 | 0.5 | 0.1 | 0.3 | | | | |
| C17 | 1.0 | 1.0 | 1.0 | 1.0 | | | | |
| C18 | 0.8 | 0.7 | 0.8 | 0.6 | | | | |
| C19 | 0.3 | 0.4 | 0.3 | 0.3 | | | | |
| C20 | 3.6 | 1.6 | 0.2 | 0.6 | | | | |
| C21 | 0.7 | 0.4 | 0.5 | 0.6 | | | | |
| C22 | 1.6 | 0.6 | 0.3 | 0.7 | | | | |
| C23 | 1.6 | 0.5 | 0.4 | 0.9 | | | | |
| C24 | 2.1 | 0.9 | 0.5 | 1.4 | | | | |
| C25 | 5.1 | 1.9 | 1.4 | 3.0 | | | | |
| C26 | 1.1 | 0.6 | 0.3 | 0.6 | | | | |
| C27 | 1.1 | 0.4 | 0.4 | 0.6 | | | | |
| C28 | 1.3 | 0.6 | 0.3 | 0.6 | | | | |
| C29 | 0.6 | 0.1 | 0.5 | 0.3 | | | | |
| C30 | 1.9 | 1.6 | 1.7 | 1.9 | | | | |
| C31 | 0.9 | 0.3 | 0.4 | 0.9 | | | | |
| C32 | 1.8 | 0.6 | 1.9 | 4.7 | | | | |

Notes: Size Classification

| | Particle Size (mm) |
|---|---|
| Pebbles | 4~64 |
| Granules | 2~4 |
| Very Coase Sand | 1~2 |
| Coase Sand | 1/2~1 |
| Medium Sand | 1/4~1/2 |
| Fine Sand | 1/8~1/4 |
| Very Fine Sand | 1/16~1/8 |
| Silt | 1/256~1/16 |
| Clay | <1/256 |

Remarks: Dry Base

Table 3.7.5: Basic Statistical Table of Bottom Sediment in Third Field Survey (Sampling in February, 1989)

| Parameter / Item | Unit | Sample Number | Max. | Min. | Ave. | S.D. |
|---|---|---|---|---|---|---|
| Specific Gravity | — | 20 | 2.85 | 2.75 | 2.79 | 0.03 |
| Specific Surface Area | $m^2/g$ | 20 | 0.82 | 0.0047 | 0.31 | 0.29 |
| Hg | ppm | 20 | 0.25 | <0.01 | 0.06 | 0.07 |
| Pb | ppm | 20 | 6 | <1 | 2 | 1 |
| Cd | ppm | 20 | 0.1 | <0.1 | 0.1 | 0.0 |
| Cr | ppm | 20 | 116 | 31 | 70 | 30 |
| Cu | ppm | 20 | 23 | <1 | 7 | 6 |
| Zn | ppm | 20 | 26 | <1 | 10 | 8 |
| Sn | ppm | 20 | <10 | <10 | <10 | — |
| TOC | % | 20 | 1.32 | 0.13 | 0.57 | 0.39 |
| Oil | ppm | 20 | 72 | 5 | 26 | 18 |

(f) Lead (Pb)

At Site 1-A, Site 1-B and Site 1-C near the sea water intake facilities of Umm Al Nar Station where the silty portion is large, lead of 4 to 6 ppm was detected, showing a little higher value in the same way as the second field survey. At all the sites, lead was in the range of less than 1 to 23 ppm, and no lead contamination was recognized.

(g) Cadmium (Cd)

Cadmium was less than 0.1 ppm at all the sites, and no cadmium contamination was recognized.

(h) Chromium (Cr)

Chromium was in the range of 31 to 116 ppm, and no chromium pollution was recognized.

(i) Copper (Cu)

Copper was in the range of less than 1 to 23 ppm. At Site 1-A, Site 1-B and Site 1-C near the sea water intake facilities of Umm Al Nar Station and Site 5-A near the brine discharge facilities of Umm Al Nar Station as well as at Site 8, copper of more than 10 ppm was detected and presented a little higher value when compared with the other sites.

The distribution tendency was almost the same between the second field survey and the third field survey.

(j) Zinc (Zn)

Zinc was in the range of less than 1 to 26 ppm. At Site 1-A, Site 1-B and Site 1-C near the sea water intake facilities of Umm Al Nar Station and Site 5-C near the brine discharge facilities of Umm Al Nar Station, zinc of 17 to 27 ppm was detected, showing a little higher value, compared to the other sites.

The distribution tendency was almost the same between the second field survey and the third field survey.

(k) Tin (Sn)

Tin was less than 10 ppm at all the sites, no condition of pollution caused by tin was recognized.

(l) Total Organic Carbon (TOC)

TOC was in the range of 0.13 to 1.32%, and was high (more than 1%) at Site 1-C, Site 5-A, Site 5-C and Site 8. The distribution tendency was almost the same between the second field survey and the third field survey.

(m) Oil Content (Oil)

The oil content was in the range of 5 to 72 ppm and was high at Site 8 (72 ppm) and Site 13 (44 ppm). Also, at the sites around Umm Al Nar Station where there are many silty sediments, a tendency towards high content was recognized in the same way as the second field survey.

In qualitative analysis using the gas chromatograph, the peak of higher hydrocarbon with the number of carbons being larger than $C_{19}$ was recognized at Site 9-B, Site 12, Site 14, Site 15, Site 16 and Site 19-A, as compared with the peak of $C_{17}$.

(6) Summary

1) *Features of Bottom Sediments around Abu Dhabi Island*

Bottom sediments around the Abu Dhabi Island showed a particle size distribution dependent on the speed of tidal currents. At the sites where the tidal currents are fast, there was a tendency for fine particles to be washed away by the currents and only coarse particles were left behind; at the sites where the tidal currents are slow, fine particles settle and the particle size distribution becomes fine.

The ratio of bottom sediments below the silty portion was large and the particle size distribution was fine at the sites near the sea water intake facilities of Umm Al Nar Station.

In the offshore area of the Abu Dhabi Island and in the neighborhood of the entrance in both the channels on both sides of the Abu Dhabi Island, the bottom sediments contained many gravels and were coarse.

Also, in both Baghal Channel and Bateen Channel on both sides of the Abu Dhabi Island, the particle size distribution was fine on both sides of the channel as compared with the center of the channel.

It is generally known that the composition of contents (heavy metal, organic matter, etc.) in the bottom sediments shows a tendency to increase as the particle size distribution becomes finer.

This is because the sediments absorb these contents more easily as the particle size distribution becomes finer. The coefficients of correlations per parameters, namely the ratio of very fine sand (below 1/8 mm), specific surface area, mercury, lead, chromium, copper, zinc, TOC and oil content in the bottom sediments, are shown in Table 3.7.6.

The coefficient of correlation between mercury, lead, copper, zinc and TOC and the ratio below very fine sand was 0.6 or more, showing a tendency for these contents to increase as the particle size distribution became finer.

The value of specific surface area indicates that these contents are absorbed more easily as the particle size distribution becomes finer. As for chromium, the coefficient of correlation with the ratio below very fine sand was as low as 0.41.

Thus, the heavy metals and organic substances (TOC) around the Abu Dhabi Island correspond to the particle size distribution of bottom sediments, and it can be considered that no remarkable contamination is caused by heavy metals and organic substances.

Table 3.7.6: Correlation Coefficient among Sediment Parameters

| | Particle of <1/8mm | Specific Area |
|---|---|---|
| <1/8mm | [1.00] | |
| S.A. | [0.90] | [1.00] |
| Hg | [0.69] | [0.72] |
| Pb | [0.78] | [0.71] |
| Cr | 0.41 | 0.34 |
| Cu | [0.84] | [0.86] |
| Zn | [0.92] | [0.88] |
| TOC | [0.82] | [0.89] |
| Oil | 0.56 | 0.59 |

2) Oil Pollution around Abu Dhabi Island

The coefficient of correlation between the ratio below very fine sand (below 1/8 mm) and the oil content is smaller than that of heavy metals (excluding chromium), TOC, etc. The relation between the ratio below very fine sand and the oil content is shown in Fig. 3.7.2.

The particle size distribution at Site 13 and Site 14 in the second field survey indicates that the ratio below very fine sand is 50 or less while the oil content is as high as 80 ppm or more.

If the relations between the ratio below very fine sand and the oil content are obtained, except for data at Site 13 and Site 14, the coefficient of correlation is 0.76, which is almost the same as that between heavy metals or TOC, and the ratio below very fine sand.

Observations at Site 13 and Site 14 have indicated oil content of 81 ppm and 83 ppm respectively which were comparatively higher than other sites. However, no specific reason was found in this study.

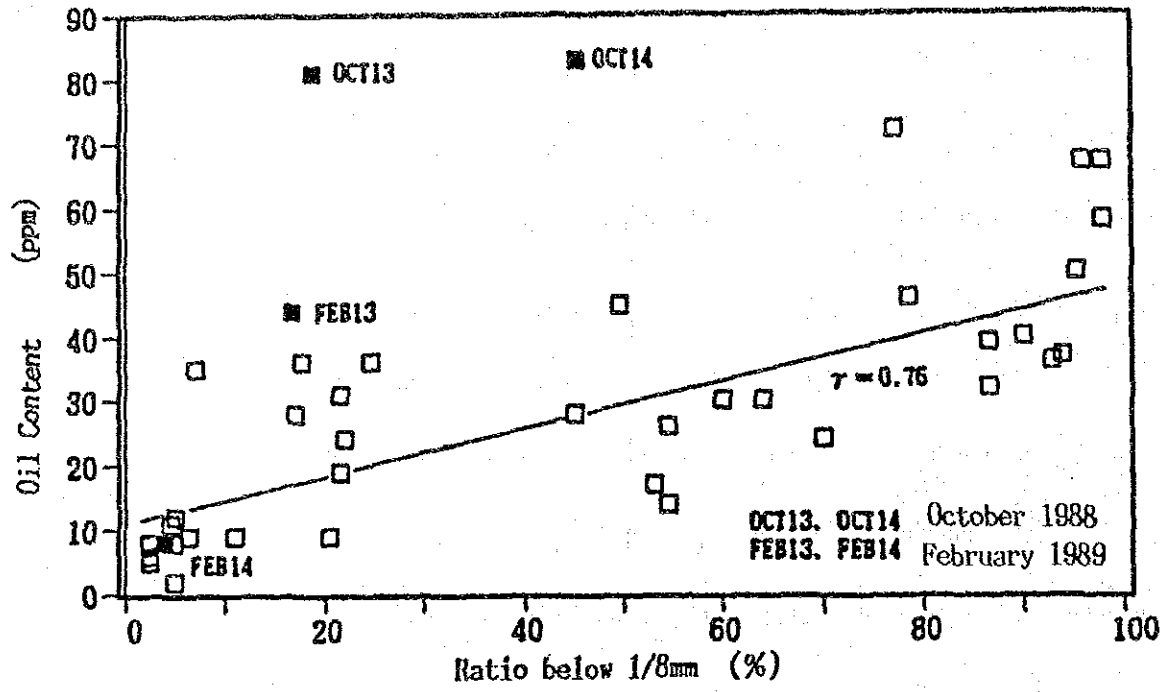



Fig. 3.7.2: Relations between Particle Content of 1/8 mm or Less and Oil Content

3.8 Marine Organisms

3.8.1 Plankton

(1) Purpose

The purpose of plankton observation is to clarify the distribution conditions of plankton in the sea around the Abu Dhabi Island.

(2) Observation Location

Observation locations are shown in Fig. 3.8.1. 5 typical locations were selected for the water sampling method and 4 typical locations, except for Site 2, were selected for the net method.

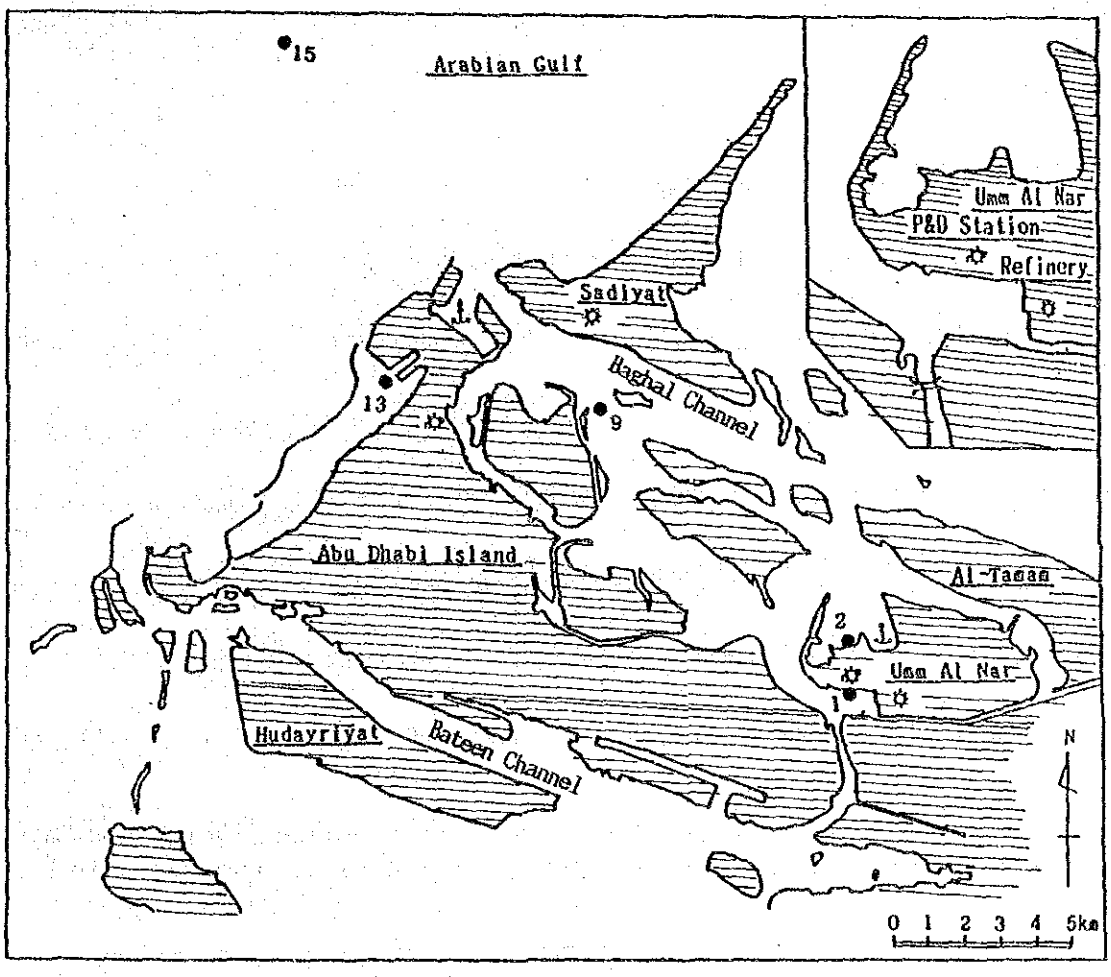



Fig. 3.8.1: Observation Location of Plankton

(3) Date of Observation

The sampling of plankton was conducted simultaneously with the observation of water quality. The sampling date of plankton is as follows:

1) Second Field Survey

* Low tide period on October 2, 1988
* High tide period on October 2, 1988

2) Third Field Survey

* Low tide period on January 31, 1989
* High tide period on February 6, 1989

(4) Method of Observation

1) Water Sampling Method for Phytoplankton and Zooplankton

10 liters of sea water was sampled from both the 0.3 m layer below the sea surface and the 1 m layer above the sea bottom with a water sampler of the Van Dorn type.

2) Net Method for Large Zooplankton

A quantitative net of the Kitahara type with a caliber of 225 mm and meshes of 0.094 mm was hauled up from 1 m above the sea bottom to the sea surface and the sampled zooplankton was observed.

(5) Results

1) Second Field Survey

(a) Phytoplankton (Water Sampling Method)

The horizontal distribution of phytoplankton is shown in Figs. 3.8.2(1) and 3.8.2(2).

a) Number of Kinds

The number of kinds of phytoplankton which occurred is shown in Table 3.8.1.

In the number of occurrence kinds, Bacillariophyceae were predominant at all the sites, with no apparent difference between the two tides.

b) Number of Cells

The number of occurrence cells of phytoplankton are shown in Tables 3.8.2(1) and (2).

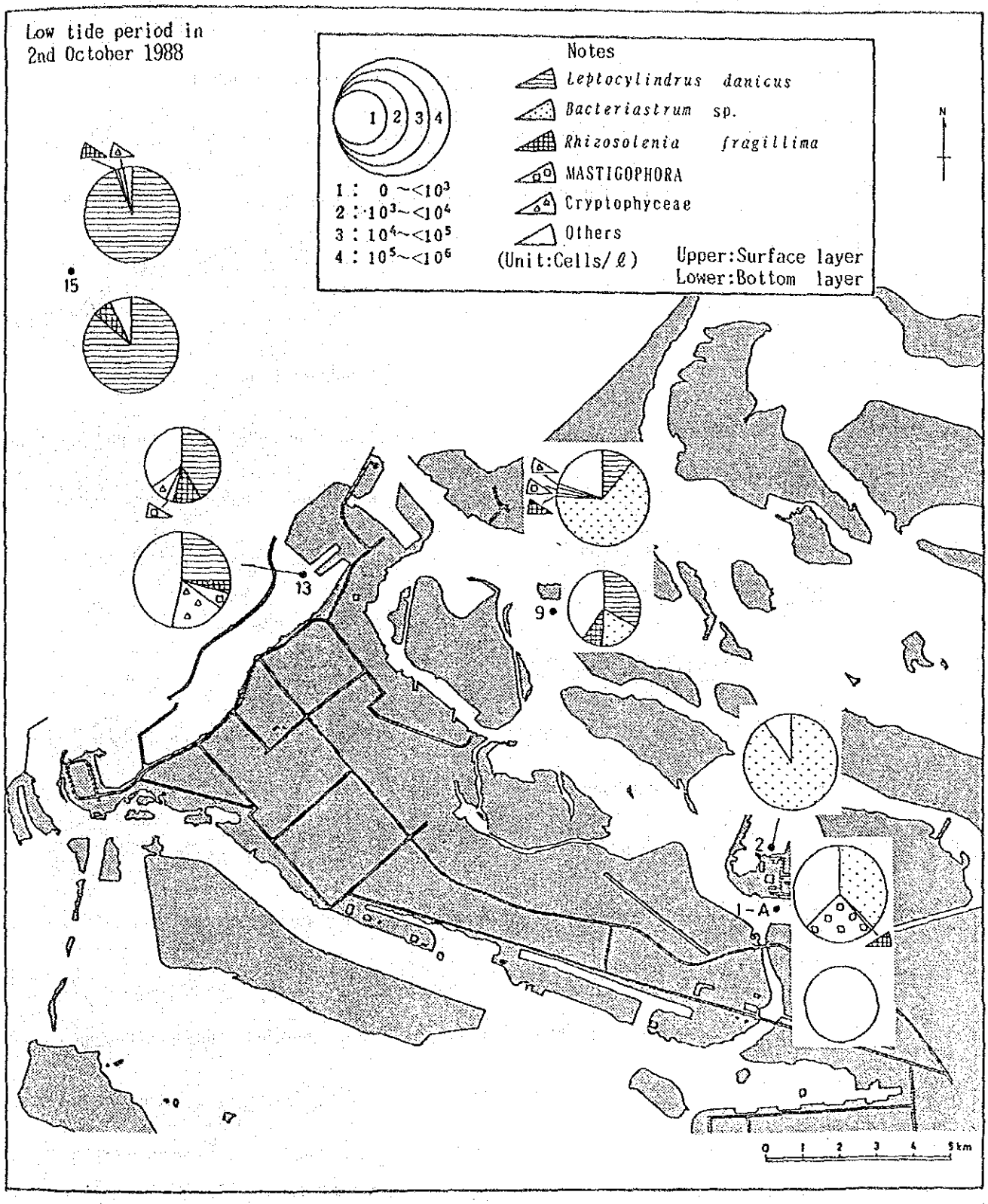



Fig. 3.8.2(1) : Horizontal Distribution of Phytoplankton by Water Sampling Method in Second Field Survey

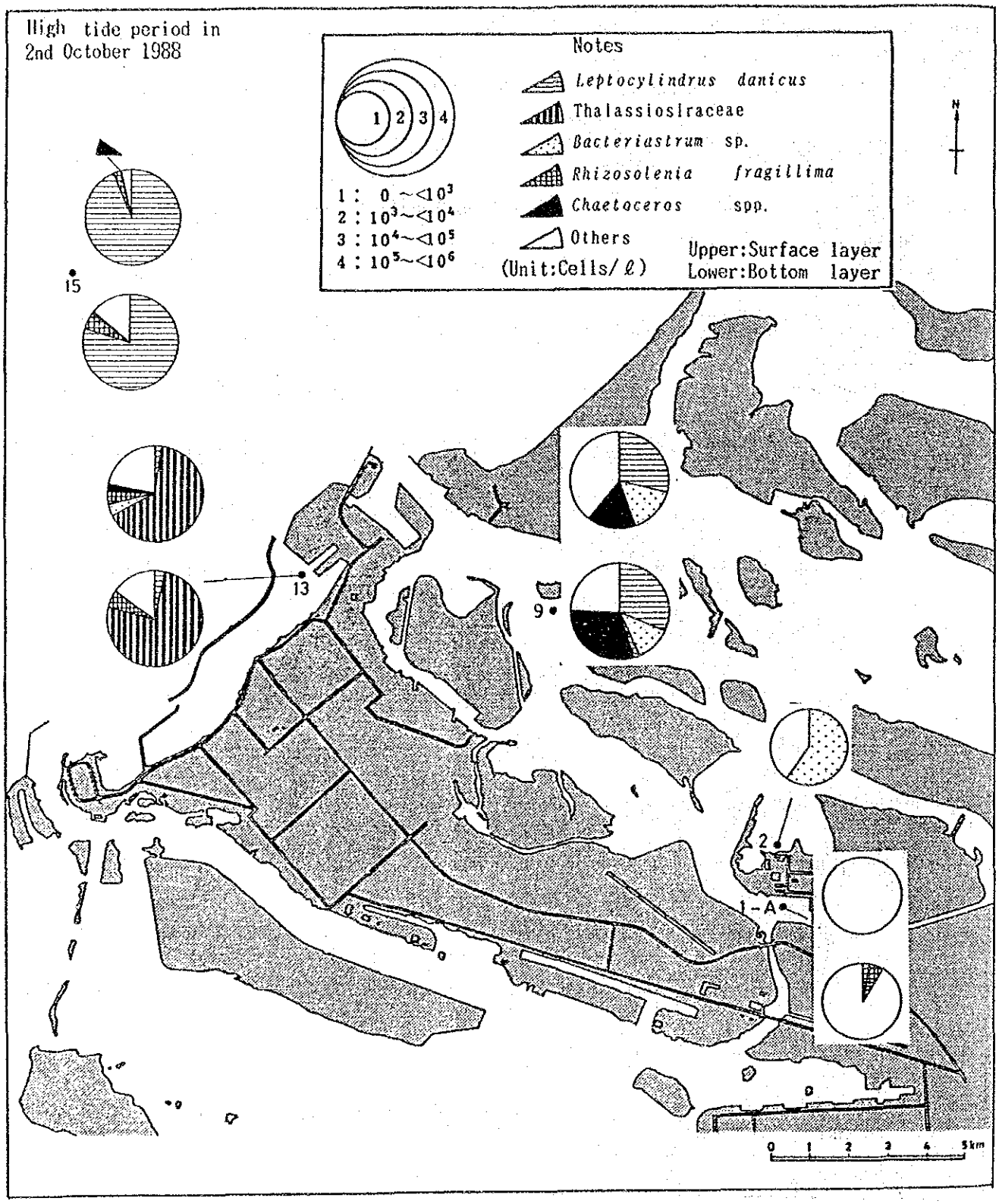



Fig. 3.8.2(2): Horizontal Distribution of Phytoplankton by Water Sampling Method in Second Field Survey

Table 3.8.1: Occurrence Kinds of Phytoplankton by Water Sampling Method in Second Field Survey

| Parameter / Tide | | Low Tide Period (2nd Oct. 1988) | High Tide Period (2nd Oct. 1988) |
|---|---|---|---|
| Whole sites | Bacillariophyceae | 21 | 23 |
| | Dinophyceae | 10 | 11 |
| | Cryptophyceae | 1 | 1 |
| | Haptophyceae | 0 | 1 |
| | Prasinophyceae | 1 | 1 |
| | Euglenophyceae | 1 | 1 |
| | Others | 1 | 1 |
| | Total | 35 | 39 |
| Range of Kinds at Each Site | | 9~18 | 9~21 |
| Average Kinds at Each Site | | 15 | 15 |

Table 3.8.2(1): Occurrence Cells of Phytoplankton by Water Sampling Method in Second Field Survey
(Low Tide Period on October 2, 1988)

| Site / Layer | 1-A | 2 | 9 | 13 | 15 | Ave. |
|---|---|---|---|---|---|---|
| Surface Layer | 14,080 | 31,680 | 27,936 | 7,632 | 72,576 | 30,781 |
| Bottom Layer | 3,264 | —— | 9,000 | 13,560 | 43,440 | 17,316 |

Unit : Cells/l

Table 3.8.2(2): Occurrence Cells of Phytoplankton by Water Sampling Method in Second Field Survey
(High Tide Period on October 2, 1988)

| Site / Layer | 1-A | 2 | 9 | 13 | 15 | Ave. |
|---|---|---|---|---|---|---|
| Surface Layer | 4,224 | 9,024 | 12,096 | 21,168 | 96,240 | 28,550 |
| Bottom Layer | 3,408 | —— | 14,640 | 44,928 | 43,392 | 26,592 |

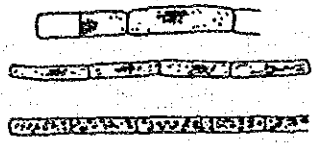
Unit : Cells/l

The average number of occurrence cells in all the layers was 24,796 cells/l during the low tide period and 27,880 cells/l during the high tide period. Also, the number of occurrence cells at the sites showed a tendency to decrease at Site 1-A near the sea water intake facilities of Umm Al Nar Station and increasing at offshore Site 15.

c) Composition of Kinds

As shown in Fig. 3.8.2, there were differences in the composition of occurrence kinds among the sites. At offshore Site 15, *Leptocylindrus danicus** were predominant and accounted for 79.9 to 94.2% of the total number of cells. Also, this kind was rarely found at Site 1-A near the sea water intake facilities of Umm Al Nar Station and at Site 2 near the brine discharge facilities of Umm Al Nar Station. Further, at Site 2, *Bacteriastrum* sp. was predominant.

Notes: * A species of Bacillariophyceae. Their cells are cylindrical in shape, 6 to 12 $\mu$m in diameter and 2 to 10 times as long as diameter. They have coastal and bay area character and are distributed in a wide range of all oceans.



*Leptocylindrus danicus*

(b) Zooplankton (Water Sampling Method)

The horizontal distribution of zooplankton is shown in Figs. 3.8.3(1) and 3.8.3(2).

a) Number of Kinds

The number of occurrence kinds of zooplankton is tabulated in Table 3.8.3.

Table 3.8.3: Occurrence Kinds of Zooplankton by Water Sampling Method in Second Field Survey

| Parameter | Site | Low Tide Period (2nd Oct. 1988) | High Tide Period (2nd Oct. 1988) |
|---|---|---|---|
| Whole sites | Ciliata | 15 | 15 |
| | Foraminifera | 1 | 1 |
| | Hydrozoa | 1 | 0 |
| | Rotifera | 1 | 1 |
| | Nematoda | 1 | 1 |
| | Copepoda | 16 | 12 |
| | Appendiculata | 4 | 4 |
| | Larva | 5 | 5 |
| | Total | 44 | 39 |
| Range of Kinds at Each Site | | 11~25 | 8~28 |
| Average Kinds at Each Site | | 19 | 18 |

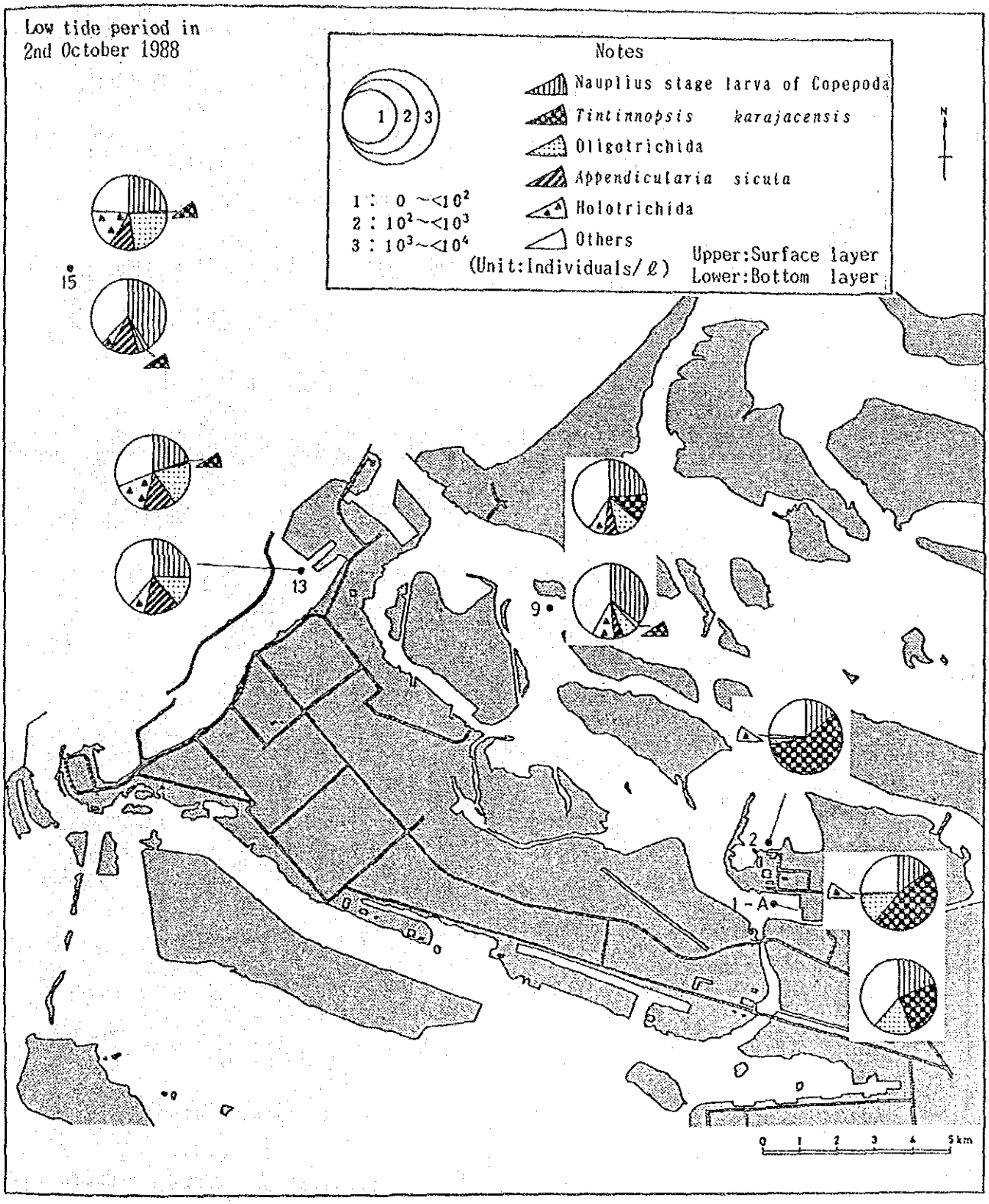



Fig. 3.8.3(1) : Horizontal Distribution of Zooplankton by Water Sampling Method in Second Field Survey

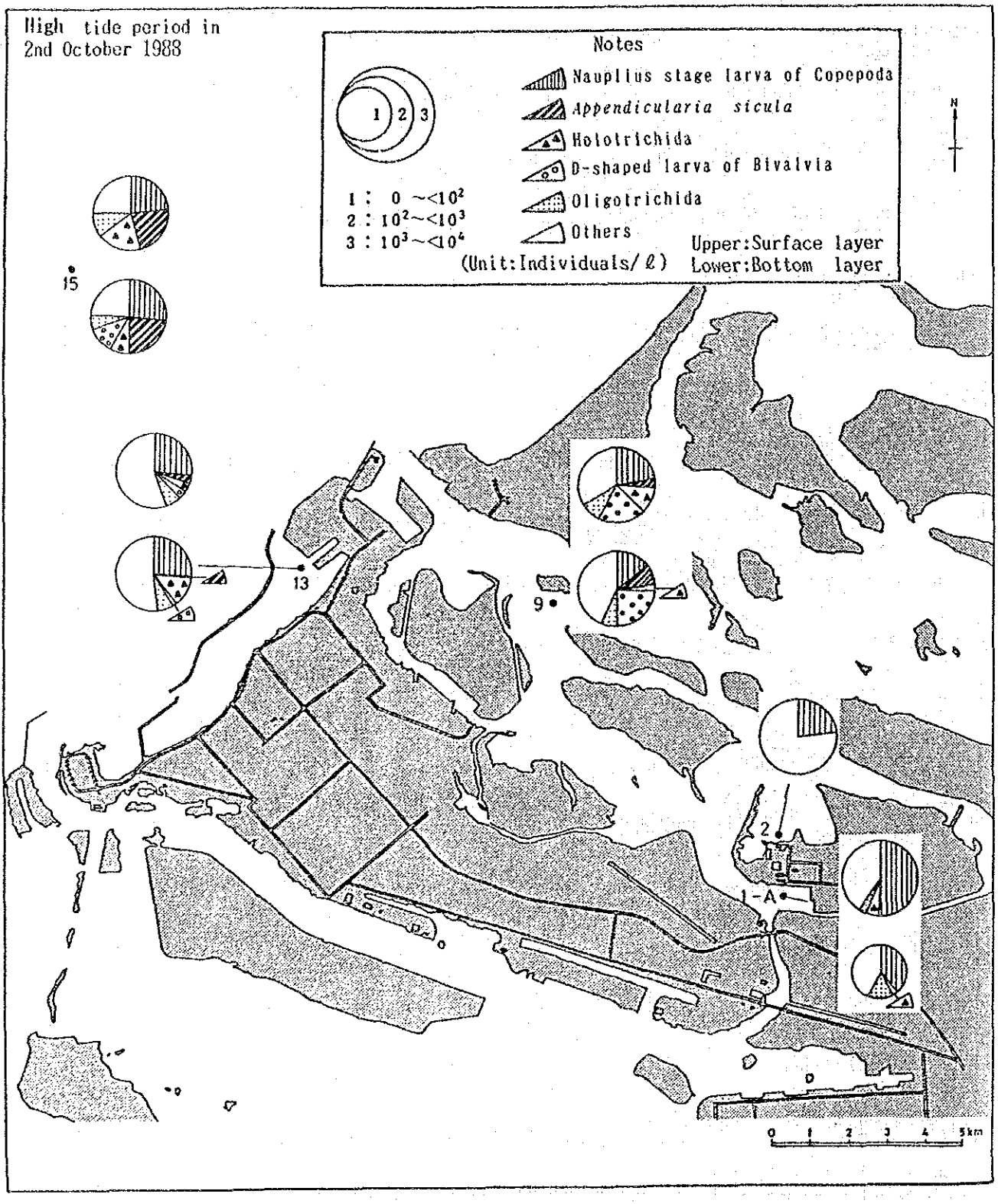



Fig. 3.8.3(2) : Horizontal Distribution of Zooplankton by Water Sampling Method in Second Field Survey

In the number of occurrence kinds at all the sites, Ciliata and Copepoda were predominant both during the low tide period and the high tide period. Also, the number of occurrence kinds at Site 1-A near the sea water intake facilities of Umm Al Nar Station, and Site 2 near the brine discharge facilities of Umm Al Nar Station was smaller, compared with the other sites.

b) Number of Individuals

The number of occurrence individuals of zooplankton is tabulated in Tables 3.8.4(1) and 3.8.4(2).

The average number of occurrence individuals in all the layers amounted to 306 individuals/l during the low tide period and 302 individuals/l during the high tide period. Also, the number of occurrence individuals at a site was found to have a tendency to increase at offshore Site 15 a little more than at other sites.

Table 3.8.4(1) : Occurrence Individuals of Zooplankton by Water Sampling Method in Second Field Survey
(Low Tide Period on October 2, 1988)

| Site / Layer | 1-A | 2 | 9 | 13 | 15 | Ave. |
|---|---|---|---|---|---|---|
| Surface Layer | 249 | 277 | 384 | 176 | 566 | 330 |
| Bottom Layer | 141 | — | 207 | 346 | 404 | 275 |

Unit : Individuals/l

Table 3.8.4(2) : Occurrence Individuals of Zooplankton by Water Sampling Method in Second Field Survey
(High Tide Period on October 2, 1988)

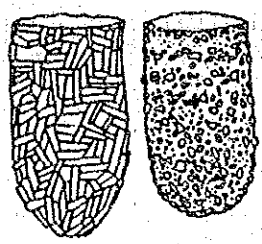
| Site / Layer | 1-A | 2 | 9 | 13 | 15 | Ave. |
|---|---|---|---|---|---|---|
| Surface Layer | 115 | 113 | 546 | 161 | 843 | 356 |
| Bottom Layer | 76 | — | 275 | 246 | 341 | 235 |

Unit : Individuals/l

c) Composition of Kinds

As shown in Fig. 3.8.3, a tendency was found that the proportion of *Tintinnopsis karajacensis** was expanding at Site 1-A near the sea water intake facilities of Umm Al Nar Station and Site 2 near the brine discharge facilities of Umm Al Nar Station, the phenomenon being especially conspicuous during the low tide period. Except for this, the proportion of nauplius larva of Copepoda was generally large at all the sites.

Notes: * A species of Ciliata. Their shell is cylindrical in shape, round at the back end, and 60 to 80 $\mu$m long, with an aperture of 30 to 40 $\mu$m. They are widely distributed in warm sea areas or the tropical zone of the Pacific, the Atlantic and the Indian Ocean.



*Tintinnopsis karajacensis*

(c) Zooplankton (Net Method)

The horizontal distribution of zooplankton is shown in Figs. 3.8.4(1) and (2).

a) Number of Kinds

The number of occurrence kinds of zooplankton is tabulated in Table 3.8.5.

Table 3.8.5: Occurrence Kinds of Zooplankton by Net Method in Second Field Survey

| Parameter | Site | Low Tide Period (2nd Oct. 1988) | High Tide Period (2nd Oct. 1988) |
|---|---|---|---|
| Whole Sites | Ciliata | 6 | 3 |
| | Hydrozoa | 1 | 1 |
| | Copepoda | 17 | 18 |
| | Appendiculata | 3 | 3 |
| | Larva | 10 | 8 |
| | Total | 37 | 33 |
| Range of Kinds at Each Site | | 14~24 | 13~24 |
| Average Kinds at Each Site | | 19 | 20 |

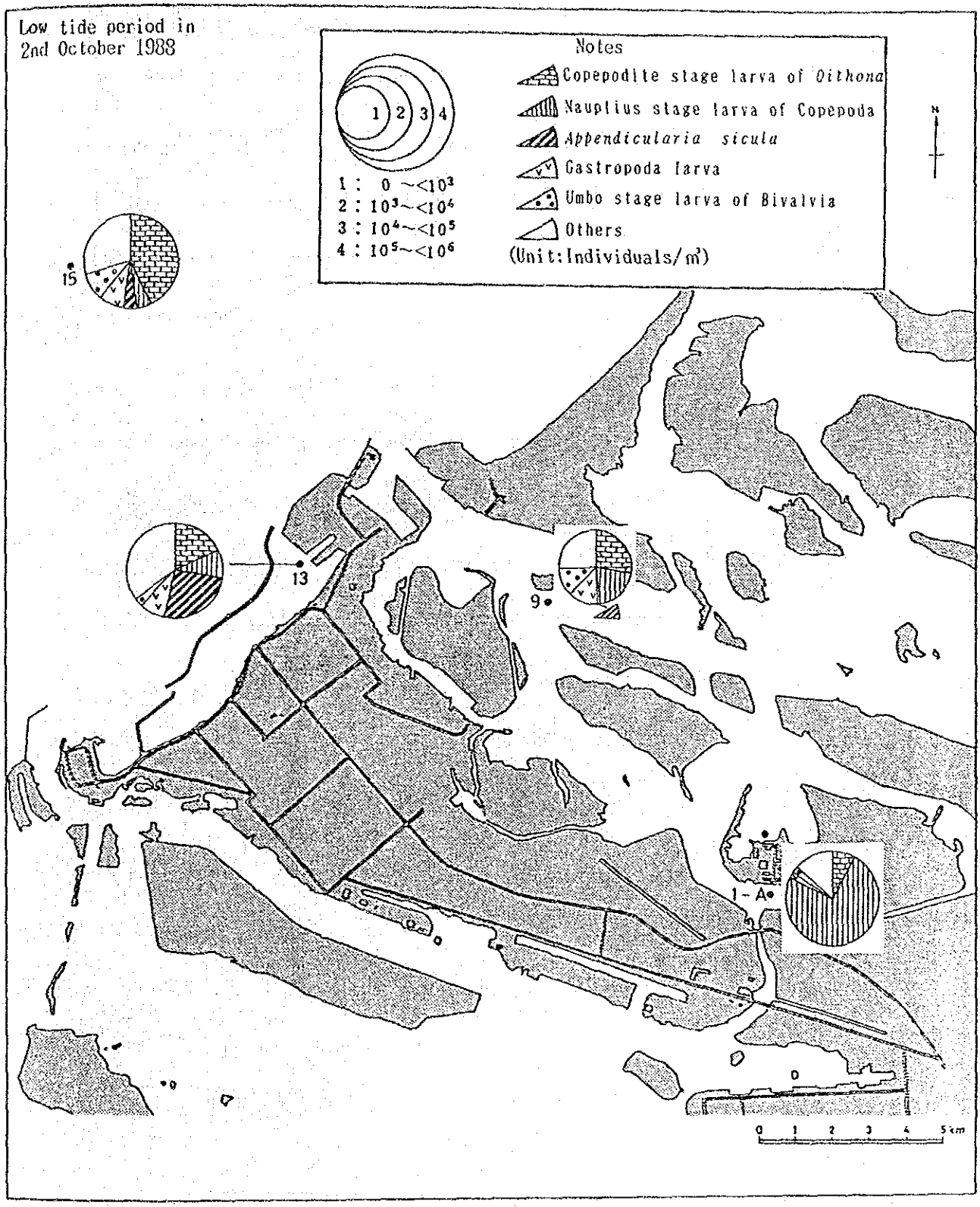



Fig. 3.8.4(1): Horizontal Distribution of Zooplankton by Net Method in Second Field Survey

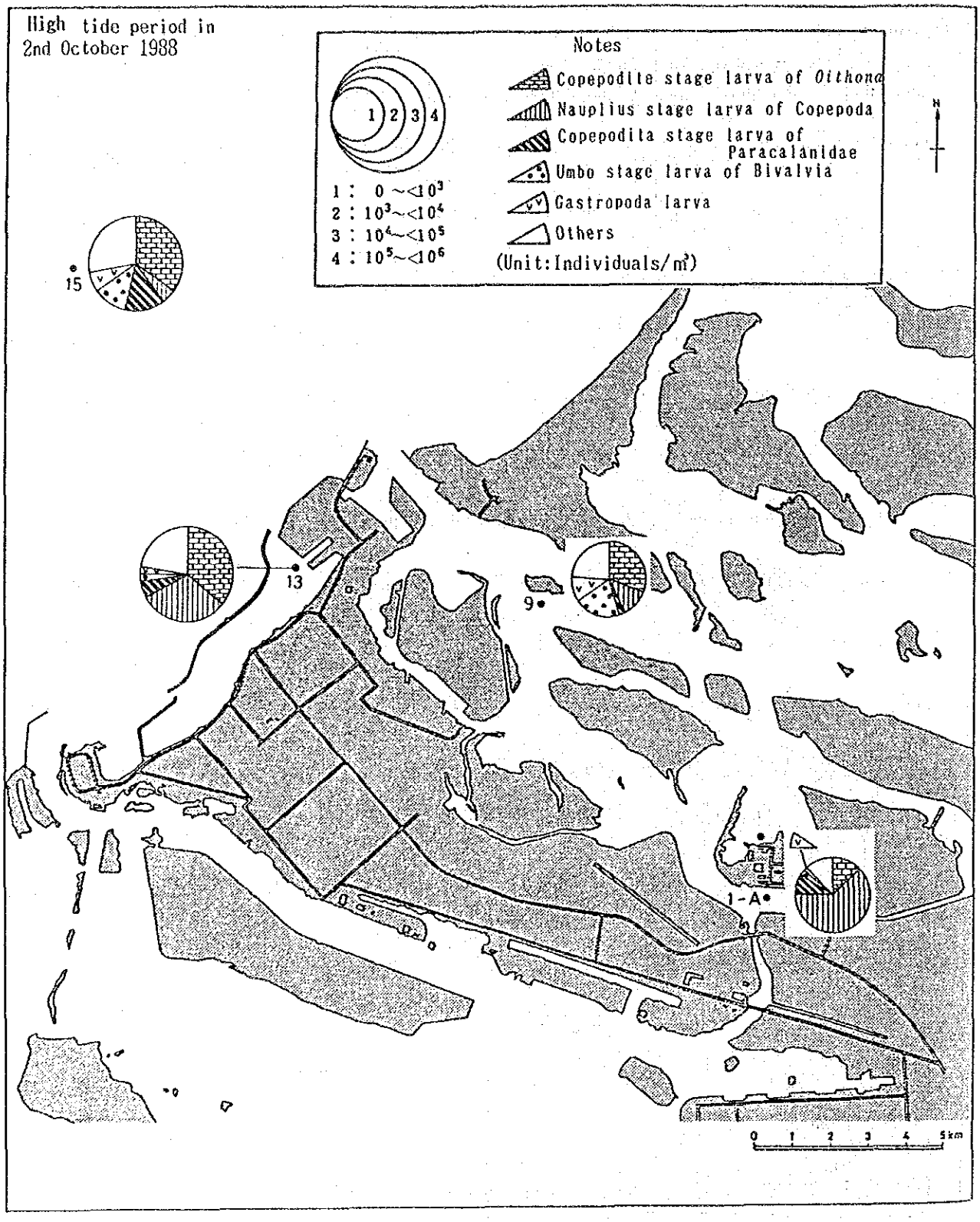



Fig. 3.8.4(2): Horizontal Distribution of Zooplankton by Net Method in Second Field Survey

In the number of occurrence kinds at all the sites, Copepoda and larvae were predominant both during the low tide period and the high tide period.

b) Number of Individuals

The number of occurrence individuals of zooplankton is shown in Table 3.8.6. The average number of occurrence individuals amounted to 17,000 individuals/m³ during the low tide period and 19,684 individuals/m³ at the high tide period. Also, the number of occurrence individuals at Site 9 in Baghal Channel seemed to be a little smaller than that at the other sites.

Table 3.8.6: Occurrence Individuals of Zooplankton by Net Method in Second Field Survey

| Site / Tide | 1-A | 9 | 13 | 15 | Ave. |
|---|---|---|---|---|---|
| Low Tide Period (2nd Oct. 1988) | 16,498 | 8,274 | 15,150 | 28,080 | 17,001 |
| High Tide Period (2nd Oct. 1988) | 9,653 | 9,419 | 35,344 | 24,320 | 19,684 |

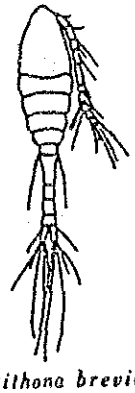
Unit : Individuals/l

c) Composition of Kinds

As shown in Figs. 3.8.4(1) and 3.8.4(2), a difference in the composition of occurrence kinds was found among the sites. At Site 1-A near the sea water intake facilities of Umm Al Nar Station, nauplius stage larva of Copepoda were predominant and accounted for 61.6 to 74.5% of the total number of individuals.

Also, at Site 9 in Baghal Channel and offshore Site 15, the number of copepodita stage larva of *Oithona* genus was relatively large. Further, so far as adults are concerned, the number of *Oithona bervicornis** was the most predominant of all the occurrence Copepoda and they were widely distributed in the sea around the Abu Dhabi Island.

Notes: * Body 0.5 to 0.8 mm long and 0.15 mm wide. Very widely distributed in warm water bay areas of the Indian Ocean, the East China Sea and other oceans.



*Oithona brevicornis*

2) Third Field Survey

(a) Phytoplankton (Water Sampling Method)

The horizontal distribution of phytoplankton is shown in Figs. 3.8.5(1) and 3.8.5(2).

a) Number of Kinds

The number of occurrence kinds of phytoplankton is tabulated in Table 3.8.7. In the number of occurrence kinds at all the sites, Bacillariophyceae and Dinophyceae were almost equal, and no difference was almost found between the two tides.

Table 3.8.7: Occurrence Kinds of Phytoplankton by Water Sampling Method in Third Field Survey

| Parameter | Tide | Low Tide Period (6th Feb. 1989) | High Tide Period (31st Jan. 1989) |
|---|---|---|---|
| Whole sites | Bacillariophyceae | 10 | 12 |
| | Dinophyceae | 11 | 9 |
| | Cryptophyceae | 1 | 1 |
| | Haptophyceae | 1 | 1 |
| | Prasinophyceae | 1 | 1 |
| | Euglenophyceae | 1 | 1 |
| | Others | 0 | 0 |
| | Total | 25 | 25 |
| Range of Kinds at Each Site | | 5~13 | 7~15 |
| Average Kinds at Each Site | | 9 | 10 |

b) Number of Cells

The number of occurrence cells of phytoplankton is tabulated in Tables 3.8.8(1) and 3.8.8(2). The average number of occurrence cells in all the layers amounted to 48,469 cells/l during the low tide period and 16,872 cells/l during the high tide period. Also, a tendency was found at the sites that the number of occurrence cells was smaller at Site 1-A near the sea water intake facilities of Umm Al Nar Station and Site 2 near the brine discharge facilities of Umm Al Nar Station and larger at offshore Site 15.

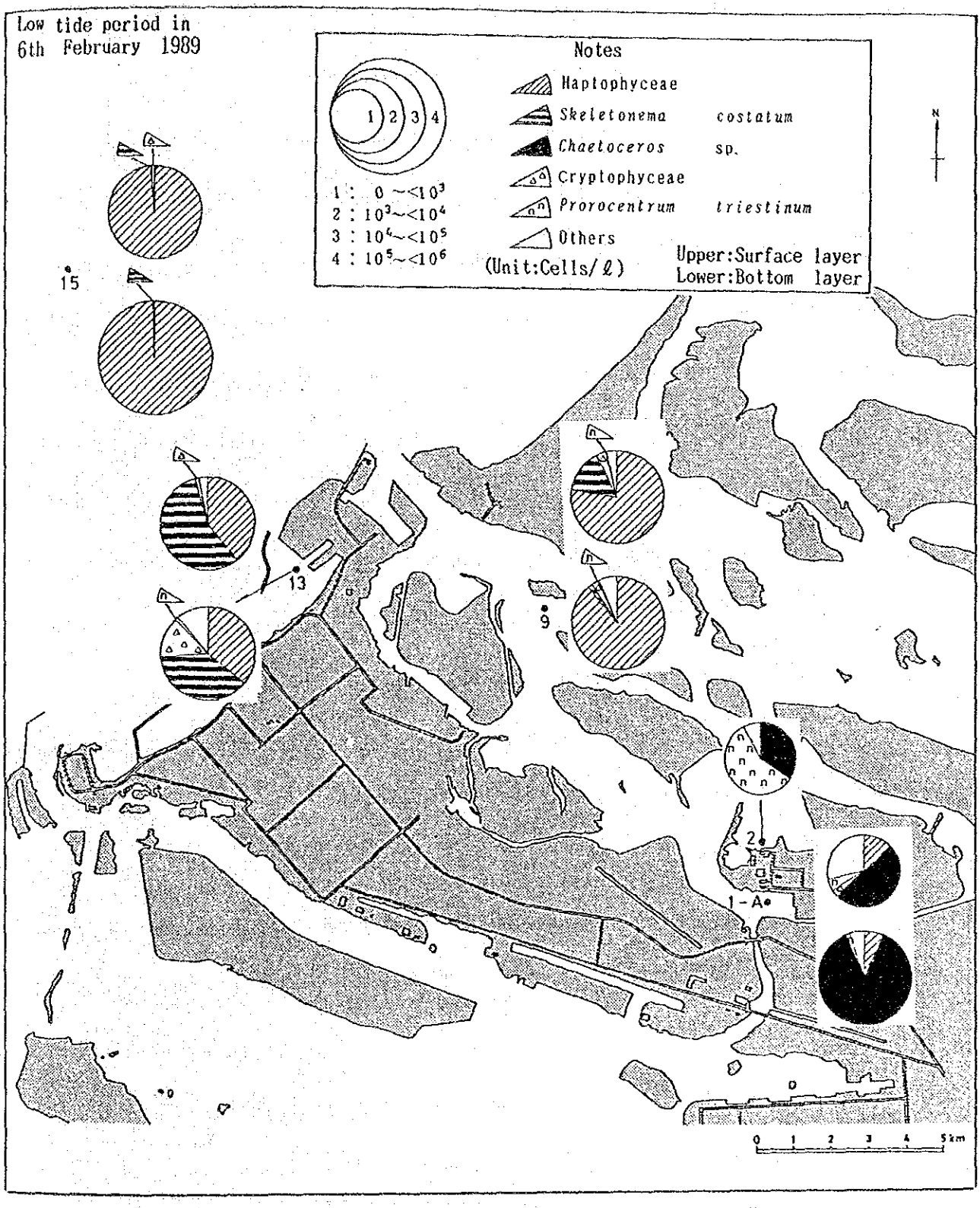



Fig. 3.8.5(1): Horizontal Distribution of Phytoplankton by Water Sampling Method in Third Field Survey

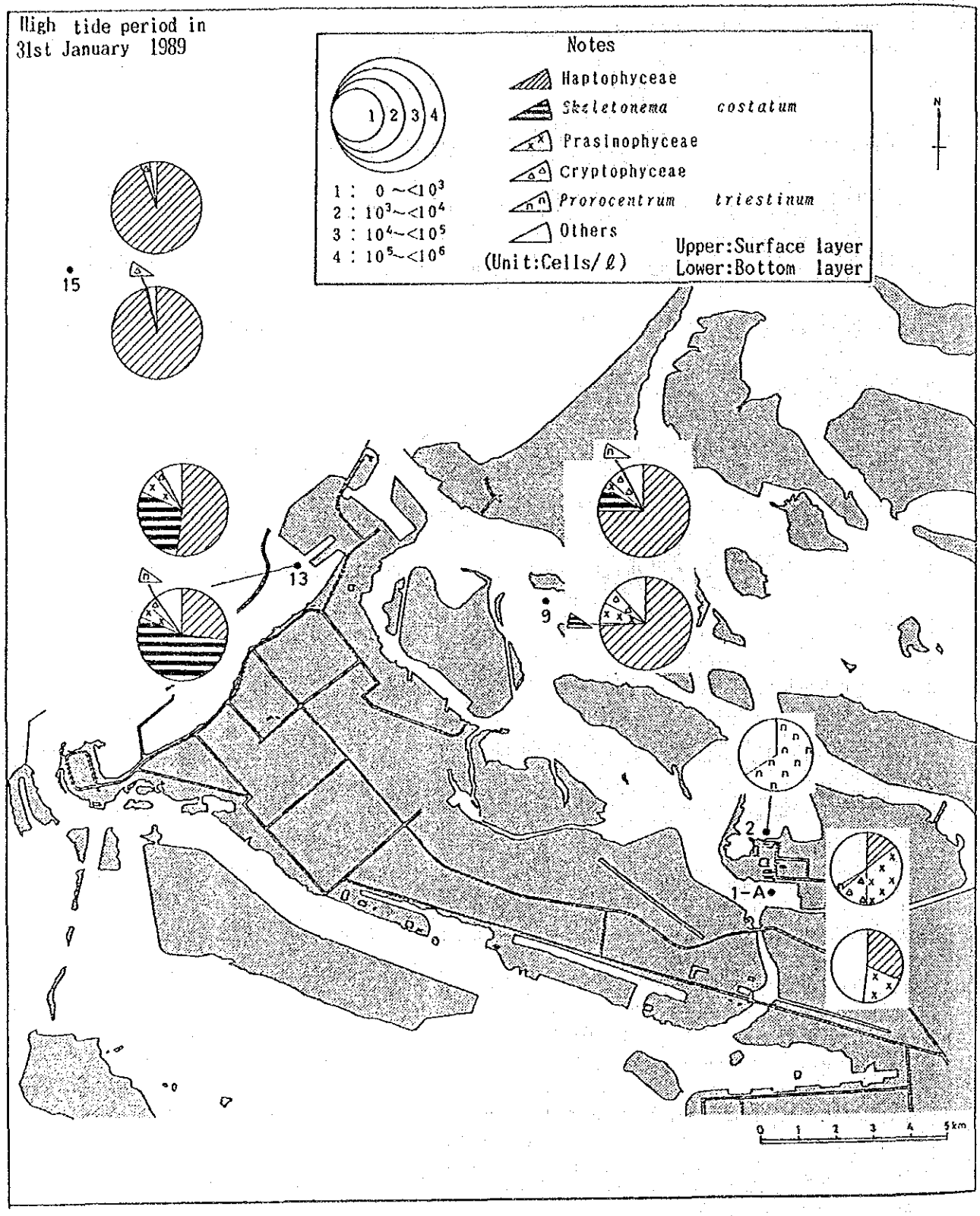



Fig. 3.8.5(2) : Horizontal Distribution of Phytoplankton by Water Sampling Method in Third Field Survey

Table 3.8.8(1) : Occurrence Cells of Phytoplankton by Water Sampling Method in Third Field Survey
(Low Tide Period on February 6, 1989)

| Site / Layer | 1-A | 2 | 9 | 13 | 15 | Ave. |
|---|---|---|---|---|---|---|
| Surface Layer | 9,120 | 7,296 | 26,112 | 50,976 | 86,400 | 35,981 |
| Bottom Layer | 26,880 | —— | 47,904 | 33,120 | 148,416 | 64,080 |

Unit : Cells/l

Table 3.8.8(2) : Occurrence Cells of Phytoplankton by Water Sampling Method in Third Field Survey
(High Tide Period on January 31, 1989)

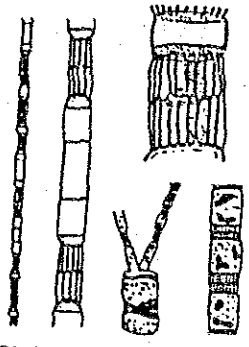
| Site / Layer | 1-A | 2 | 9 | 13 | 15 | Ave. |
|---|---|---|---|---|---|---|
| Surface Layer | 4,064 | 3,416 | 15,264 | 27,936 | 26,640 | 15,664 |
| Bottom Layer | 2,784 | —— | 14,868 | 18,432 | 37,440 | 18,381 |

Unit : Cells/l

c) Composition of Kinds

As shown in Fig. 3.8.5, the composition of occurrence kinds differed among the sites. At offshore Site 15 and Site 9 in Baghal Channel, Haptophyceae were predominant both at the low tide period and the high tide period, and in particular at Site 15, it accounted for 94.1 to 99.5% of the total number of cells. On the other hand, *Skeletonema costatum** appeared more at Site 13 in Dhow Harbour than at the other sites.

Notes: * A species of Bacilarriophyceae. Cells oval or lenticular in shape, 18 to 35 $\mu$m in diameter. It is an eurythermal and euryhaline species which appears in great quantities throughout the year in all coasts and bay areas.



*Skeletonema costatum*

(b) Zooplankton (Water Sampling Method)

The horizontal distribution of zooplankton is shown in Figs. 3.8.6(1) and 3.8.6(2).

a) Number of Kinds

The number of occurrence kinds of zooplankton is tabulated in Table 3.8.9.

In the number of occurrence kinds at all the sites, Ciliata and Copepoda were predominant. On the other hand, the number of occurrence kinds was a little smaller at the Site 1-A near the sea water intake facilities of Umm Al Nar Station and Site 2 near the brine discharge facilities of Umm Al Nar Station, compared with the other sites.

Table 3.8.9: Occurrence Kinds of Zooplankton by Water Sampling Method in Third Field Survey

| Parameter | Site | Low Tide Period (6th Feb. 1989) | High Tide Period (31st Feb. 1989) |
|---|---|---|---|
| Whole sites | Ciliata | 19 | 18 |
| | Foraminifera | 1 | 1 |
| | Rotifera | 1 | 1 |
| | Nematoda | 1 | 1 |
| | Sagittoidea | 0 | 1 |
| | Copepoda | 17 | 14 |
| | Pterophyta | 1 | 0 |
| | Appendiculata | 3 | 2 |
| | Larva | 3 | 5 |
| | Total | 46 | 43 |
| Range of Kinds at Each Site | | 7~21 | 6~23 |
| Average Kinds at Each Site | | 13 | 13 |

b) Number of Individuals

The number of occurrence individuals of zooplankton is tabulated in Tables 3.8.10(1) and 3.8.10(2). The average number of occurrence individuals in all the layers amounted to 182 individuals/l during the low tide period and 210 individuals/l during the high tide period. Also, there was not much difference in the number of occurrence individuals among the sites, except that variation between the tides was found at Site 2.

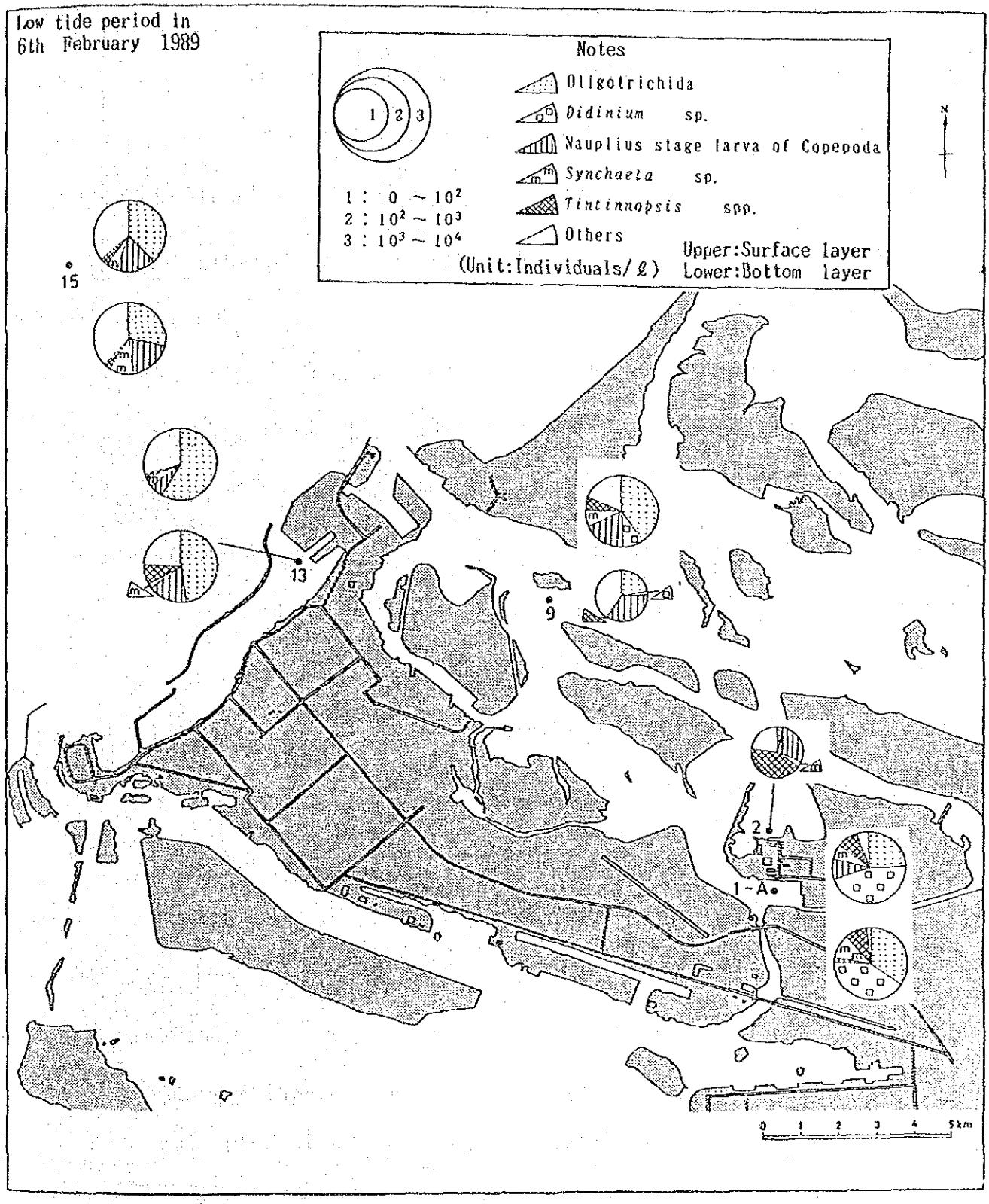



Fig. 3.8.6(1) : Horizontal Distribution of Zooplankton by Water Sampling Method in Third Field Survey

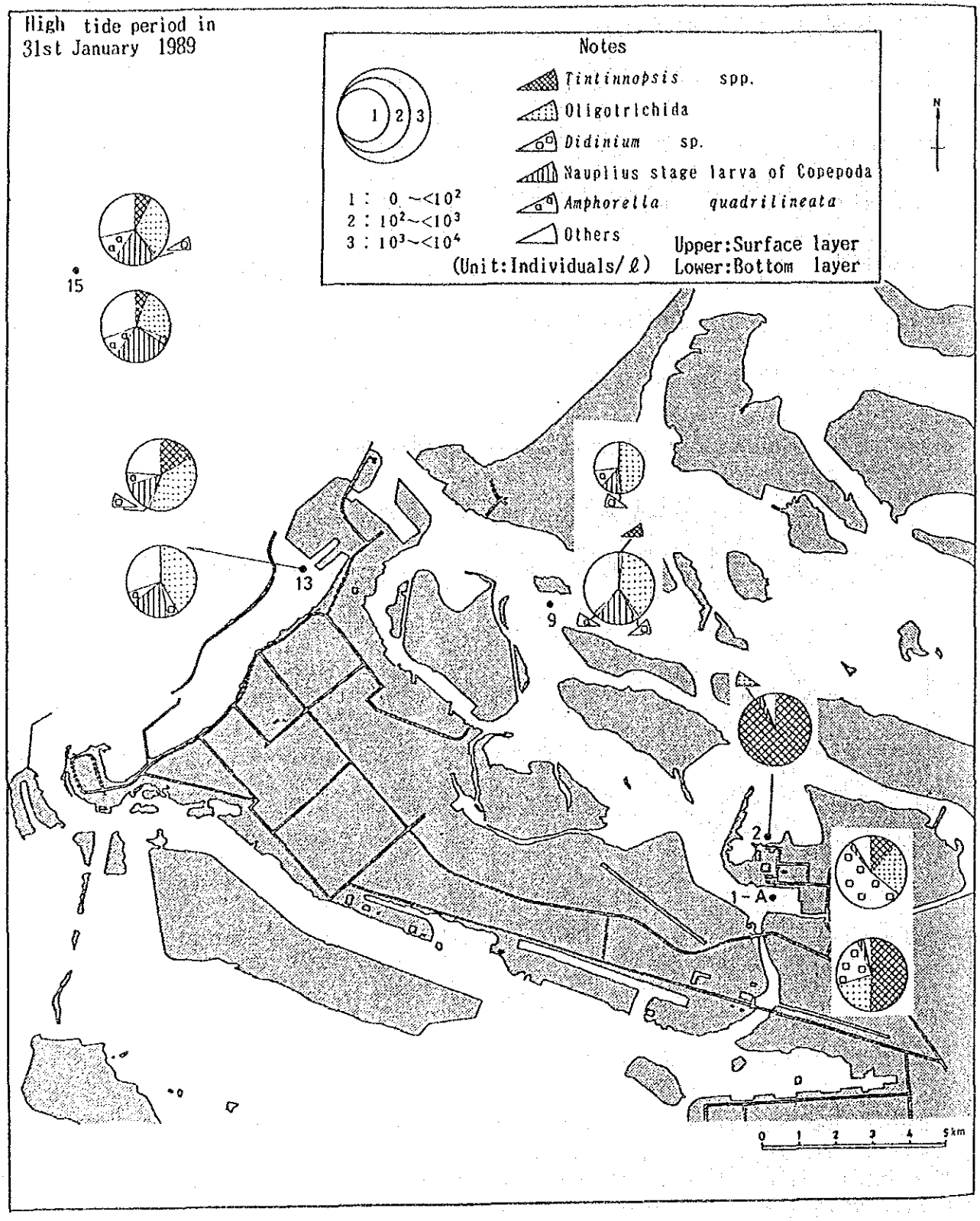



Fig. 3.8.6(2) : Horizontal Distribution of Zooplankton by Water Sampling Method in Third Field Survey

Table 3.8.10(1) : Occurrence Individuals of Zooplankton by Water Sampling Method in Third Field Survey
(Low Tide Period on February 6, 1989)

| Site / Layer | 1-A | 2 | 9 | 13 | 15 | Ave. |
|---|---|---|---|---|---|---|
| Surface Layer | 177 | 26 | 203 | 149 | 175 | 146 |
| Bottom Layer | 421 | — | 92 | 185 | 208 | 227 |

Unit : Individuals/l

Table 3.8.10(2) : Occurrence Individuals of Zooplankton by Water Sampling Method in Third Field Survey
(High Tide Period on January 31, 1989)

| Site / Layer | 1-A | 2 | 9 | 13 | 15 | Ave. |
|---|---|---|---|---|---|---|
| Surface Layer | 321 | 538 | 66 | 181 | 227 | 267 |
| Bottom Layer | 141 | — | 105 | 115 | 194 | 139 |

Unit : Individuals/l

c) Composition of Kinds

As shown in Fig. 3.8.6, a trend was found that Oligotrichida had a large number at both tides, except at Site 2. Also, *Didinium* sp. at Site 1-A during both tides and *Tintinnopsis* sp. at Site 2 during the high tide period had a large number respectively.

(c) Zooplankton (Net Method)

a) Number of Kinds

The number of occurrence kinds of zooplankton is shown in Table 3.8.11.

Copepoda was predominant at all the sites at both the tides. Also, at offshore Site 15, the total number of occurrence kinds was greater, compared with the other sites.

Table 3.8.11: Occurrence Kinds of Zooplankton by Net Method in Third Field Survey

| Parameter | Site | Low Tide Period (6th Feb. 1989) | High Tide Period (31st Feb. 1989) |
|---|---|---|---|
| Whole Sites | Ciliata | 3 | 1 |
| | Hydrozoa | 0 | 1 |
| | Rotifera | 1 | 1 |
| | Cladocea | 1 | 0 |
| | Copepoda | 27 | 20 |
| | Appendiculata | 2 | 3 |
| | Larva | 6 | 6 |
| | Total | 40 | 32 |
| Range of Kinds at Each Site | | 14~30 | 13~27 |
| Average Kinds at Each Site | | 21 | 18 |

b) Number of Individuals

The number of occurrence individuals of zooplankton is tabulated in Table 3.8.12.

The average number of occurrence individuals amounted to 7,264 individuals/m³ during the low tide period and 10,548 individuals/m³ during the high tide period. Also, the number of occurrence individuals at each site was the greatest at offshore Site 15, this phenomenon being especially conspicuous during the high tide period.

c) Composition of kinds

As shown in Figs. 3.8.7(1) and (2), a general tendency was found that at each of all the sites, copepodita larva of *Oithona* and nauplius larva of Copepoda were predominant. Also, the adults of Copepoda appeared rarely both in number of kinds and in number of individuals at Site 1-A near the sea water intake facilities of Umm Al Nar Station, and often at offshore Site 15.

Table 3.8.12 Occurrence Individuals of Zooplankton by Net Method in the Third Field Survey

| Site / Tide | 1-A | 9 | 13 | 15 | Ave. |
|---|---|---|---|---|---|
| Low Tide Period (6th Feb. 1989) | 4,430 | 9,543 | 5,083 | 10,001 | 7,264 |
| High Tide Period (31st Jan. 1989) | 3,875 | 6,278 | 4,575 | 27,462 | 10,548 |

Unit : Individuals/l

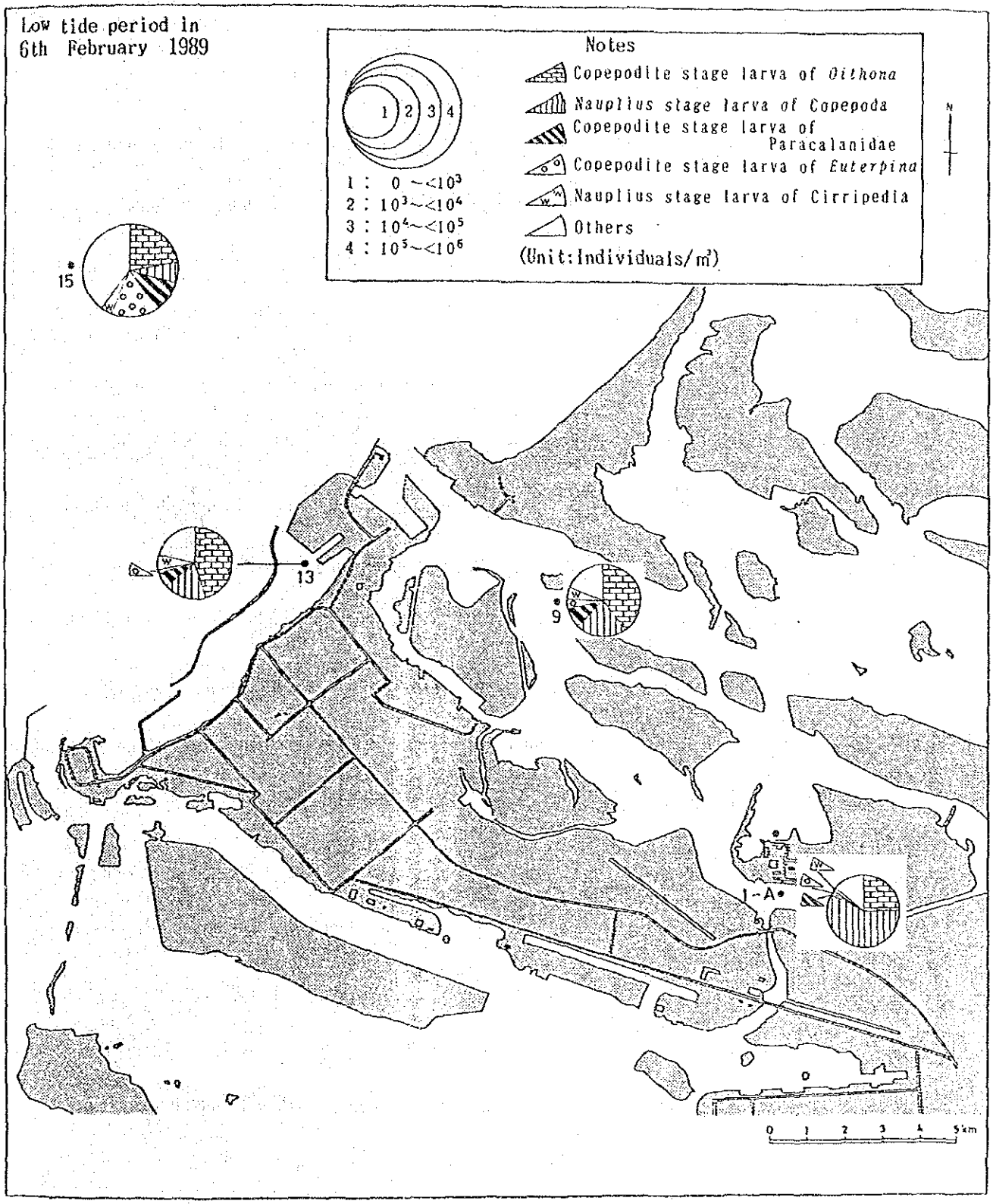



Fig. 3.8.7(1) : Horizontal Distribution of Zooplankton by Net Method in Third Field Survey

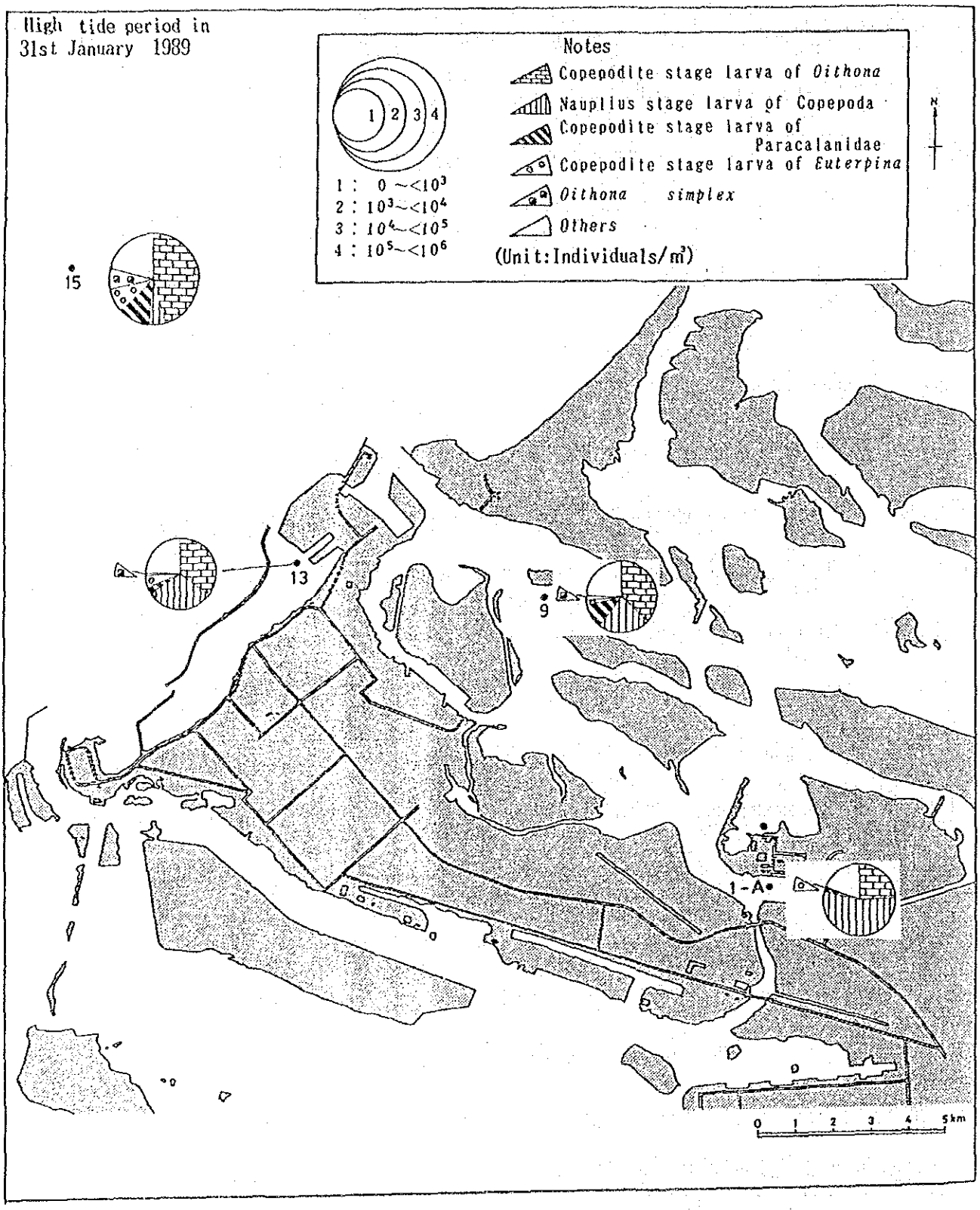



Fig. 3.8.7(2) : Horizontal Distribution of Zooplankton by Net Method in Third Field Survey

(6) Summary

1) Features in Sea around the Abu Dhabi Island

(a) Phytoplankton (Sampling Water Method)

a) Both the second field survey in summer and the third field survey in winter revealed greater number of occurrence kinds of Bacillariophyceae and Dinophyceaeas compared with the other algae. Also, the number of occurrence kinds at all the sites, seasonally considered, was a little greater in summer.

b) The average number of occurrence cells by tides in summer and in winter amounted to 1.7 to 4.8 x $10^4$ cells/l and, horizontally considered, was smaller around Umm Al Nar Station and greater in the offing.

c) The occurrence conditions of dominant kinds observationally differed among the sites and between the tides, but the definite sea area distinction was impossible due to too wide variation. Also, on the average of all the sites, *Leptocylindrus danicus* was predominant in summer and Haptophyceae in winter.

(b) Zooplankton (Sampling Water Method)

a) Both in summer and in winter, the number of occurrence kinds of Ciliata and Copepoda was predominant. Also, the number of occurrence kinds at all the sites in total, seasonally considered, was a little greater in summer.

b) The average number of occurrence individuals by tides in summer and winter came to 1.8 to 3.1 x $10^2$ individuals/l without much difference among the sites except some.

c) The occurrence conditions of dominant kinds differed according to the seasons. On the average at all the sites, nauplius larva of Copepoda were predominant in summer and Oligotrichida were prevailed in winter.

(c) Zooplankton (Net Method)

a) In summer and in winter as well, the number of occurrence kinds of Copepoda was predominant and that at all the sites was almost equal, with no seasonal variations found.

b) The number of occurrence individuals, on the average by tides in summer and winter, came to 0.7 to 2.0 x $10^4$ individuals/$m^3$ without very much difference among the sites but some.

* The occurrence conditions of dominant kinds have not shown definite seasonal variations and copepodita larva of *Oithona* genus and nauplius larva of Copepodawere predominant both in summer and in winter.

2) Plankton as Environmental Index

As for indicativity of phytoplankton, a considerably complicated aspect is presented due to large variation in occurrence kinds and quantities in eutrophicareas of coastal parts and embayment, and therefore, in many cases, it is difficult to typify it according to the chorological conditions.

Also, according to the results of surveys and tests so far conducted, it seems that the direct detrimental action of petroleum on phytoplankton emerges in relatively high concentration, with its degree of influence reportedly being different, to a considerable extent, according to the properties of petroleum and the kind of plankton.

The results of the second and third field surveys show no definite tendency in the occurrence conditions of dominant kinds of phytoplankton but indicate wide variation so that their effectiveness as an environmental index is considered to be insignificant.

Further, it is said that when phytoplankton appears in surface water in a quantity greater than 5,000 cells/ml, it is, in many cases, perceived as discolored water in a visual sense, causing, in some cases, the development of red tide (phytoplanktons more than $10^4$ cells/ml) with the progress of eutrophication in the sea area. According to the results of plankton collection and visual observation on board a vessels, the red tide phenomenon was not perceived.

In case of zooplankton, the results of the marine field surveys showed the tendency that, in net method, copepodite stage larva of *Oithona* genus and nauplius stage larva of Copepoda were dominant. These Copepoda constitute an important group as feed for sardines and other small Pisces which eat planktons, and so, it is considered necessary to keep special attention on the variation of occurrence quantities, together with those of Appendiculata (Few observed in the vicinity of Umm Al Nar Station, increasing in quantity toward the offing out of the channels. They are considered effective as an index of water mass).

3.8.2 Benthos

(1) Purpose

The purpose of benthos observation is to clarify the distribution conditions of benthos in the sea around the Abu Dhabi Island.

(2) Observation Location

The observation locations are as shown in Fig. 3.8.8. 20 locations were selected so that the distribution of benthos in the sea around the Abu Dhabi Island could be ascertained generally.

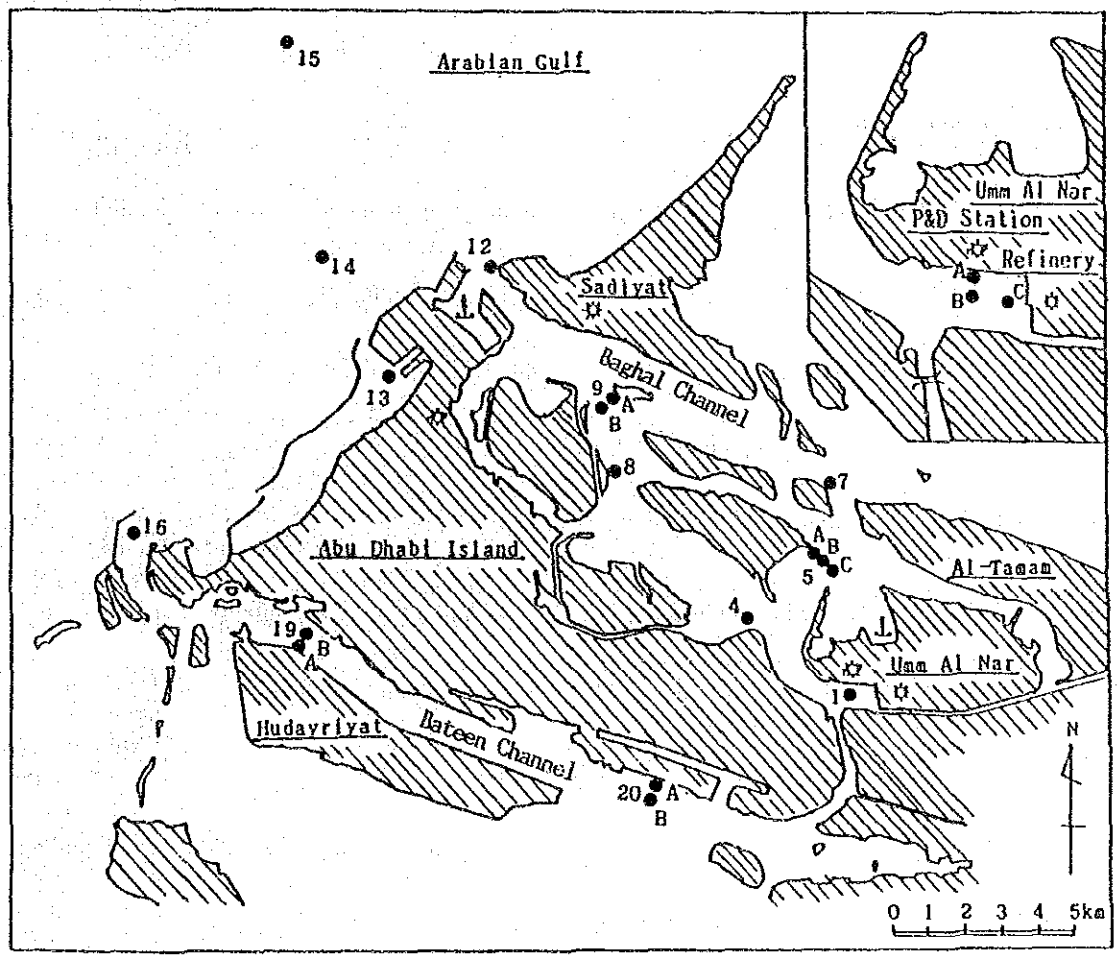



Fig. 3.8.8: Observation Location of Benthos

(3) Duration of Observation

The sampling of benthos was conducted simultaneously with the of bottom sediment. The sampling duration of benthos is as follows:

1) Second Field Survey

October 16 to 18, 1988

2) Third Field Survey

January 25 to February 4, 1989

(4) Method of Observation

The bottom sediments were sampled 3 times with a bottom sampler of the Smith-McIntyre type with a sampling area of 0.05 $m^2$ and the benthos which resided in the mesh after the sampled sediments were meshed to 1 mm, were observed.

(5) Results

1) Second Field Survey

The component distribution by division of benthos is shown in Fig. 3.8.9 and the distribution of number of kinds, individuals and Biotic of benthos are shown in Fig. 3.8.10.

(a) Number of Kinds

The number of occurrence kinds of benthos is tabulated in Table 3.8.13.

In the total number of occurrence kinds at all the sites altogether, Annelida, Mollusca and Arthropoda were predominant. Also, the average number of kinds was 21 kinds, and the number of occurrence kinds at each site was greater at Site 5-B, Site 7, Site 8, Site 19-A and Site 20-B in the channels, and at Site 14 and Site 15 in the open sea.

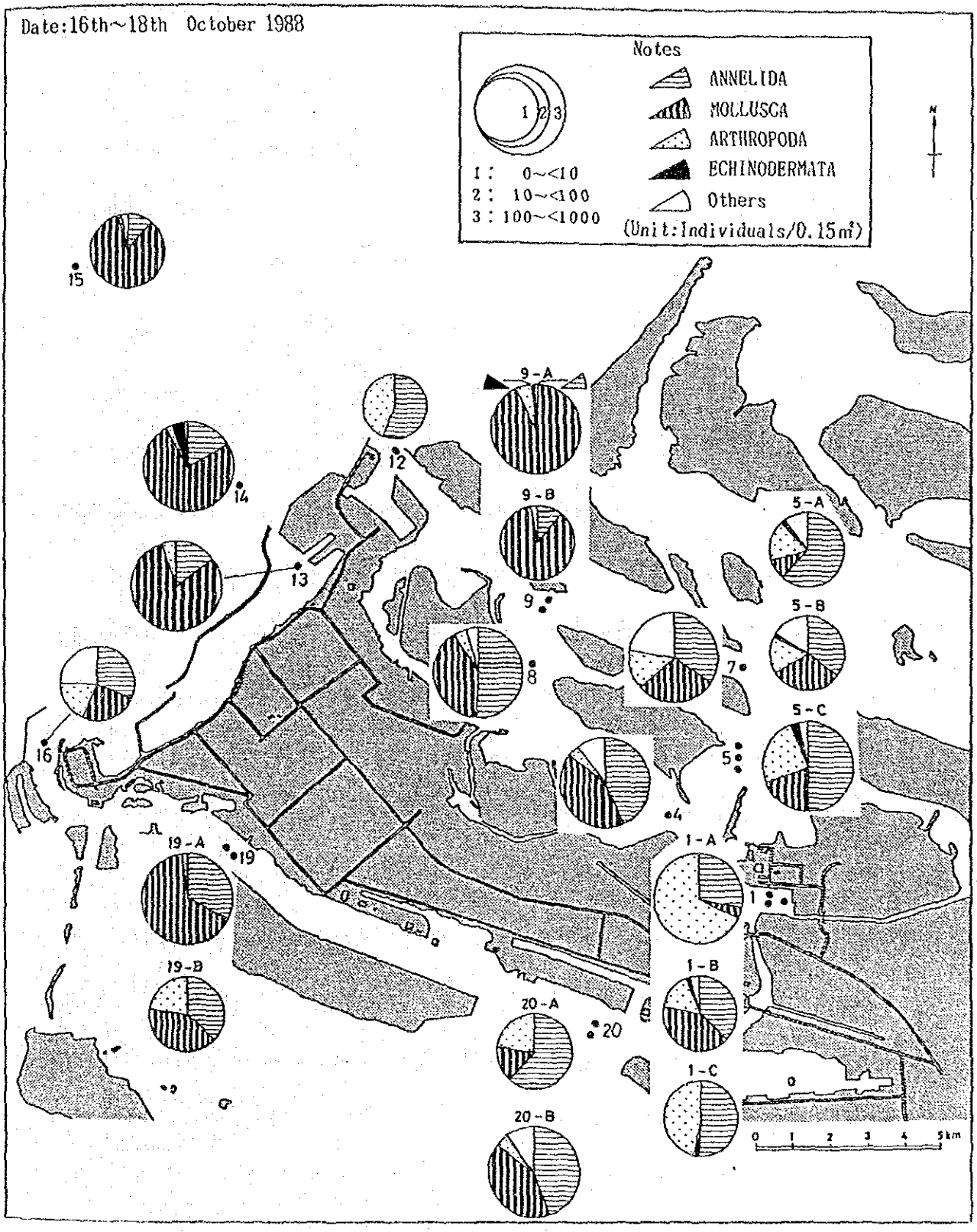



Fig. 3.8.9: Division Composition Distribution of Benthos in Second Field Survey

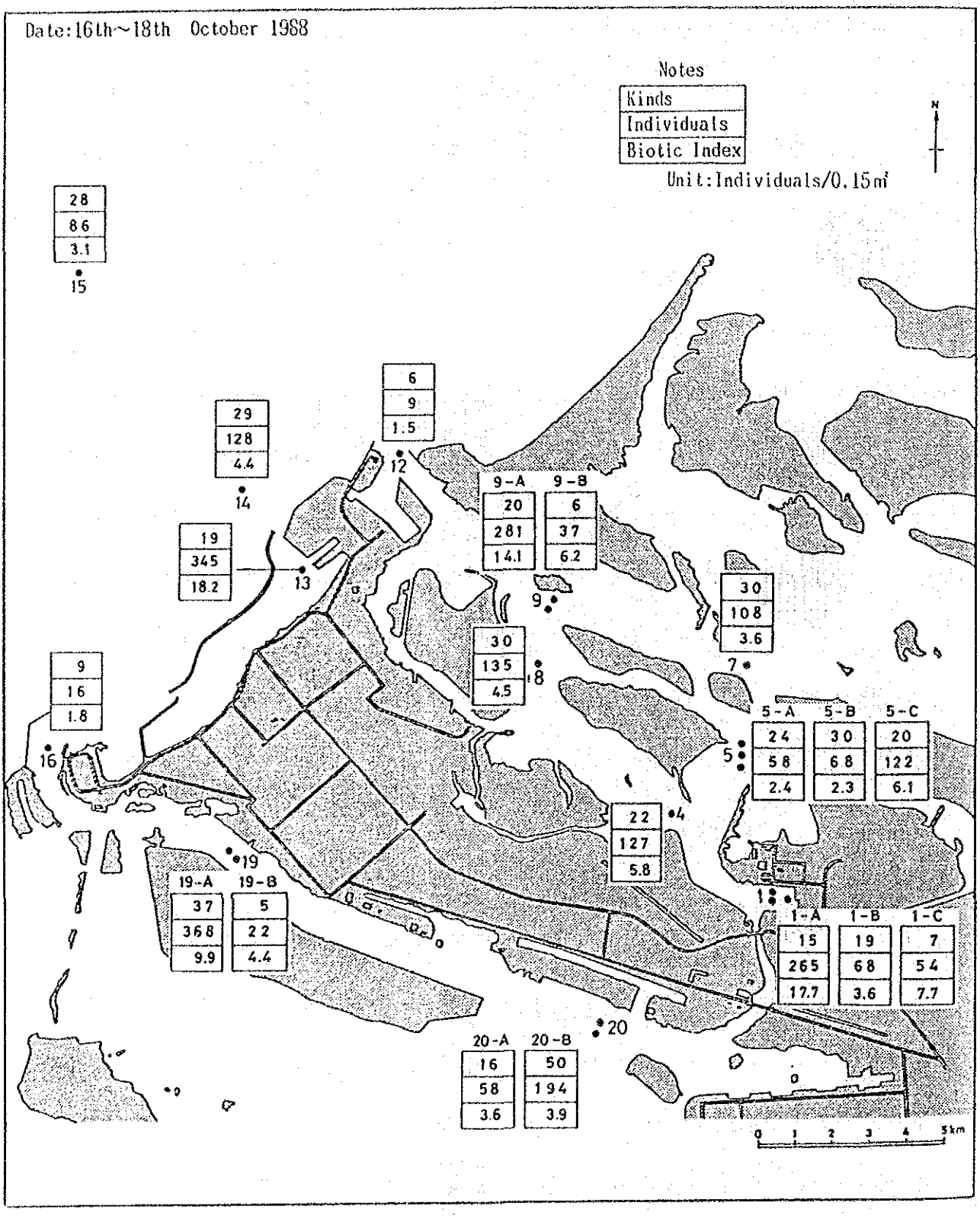



Fig. 3.8.10: Distribution of Kinds, Individuals and Biotic Index of Benthos in Second Field Survey

Table 3.8.13: Occurrence Kinds of Benthos in Second Field Survey (Sampling in October, 1988)

| Site \ Division | ① | ② | ③ | ④ | ⑤ | Others | Total |
|---|---|---|---|---|---|---|---|
| 1-A | 5 | 4 | 6 | 0 | 0 | 0 | 15 |
| 1-B | 5 | 9 | 3 | 1 | 0 | 1 | 19 |
| 1-C | 4 | 1 | 2 | 0 | 0 | 0 | 7 |
| 4 | 8 | 8 | 5 | 0 | 0 | 1 | 22 |
| 5-A | 13 | 3 | 6 | 1 | 0 | 1 | 24 |
| 5-B | 10 | 10 | 5 | 1 | 2 | 2 | 30 |
| 5-C | 12 | 2 | 3 | 1 | 0 | 2 | 20 |
| 7 | 11 | 11 | 4 | 0 | 1 | 3 | 30 |
| 8 | 15 | 11 | 2 | 0 | 0 | 2 | 30 |
| 9-A | 4 | 13 | 1 | 1 | 0 | 1 | 20 |
| 9-B | 2 | 2 | 0 | 0 | 1 | 1 | 6 |
| 12 | 3 | 0 | 2 | 0 | 0 | 1 | 6 |
| 13 | 5 | 8 | 5 | 0 | 0 | 1 | 19 |
| 14 | 9 | 16 | 1 | 1 | 0 | 2 | 29 |
| 15 | 6 | 18 | 1 | 0 | 3 | 0 | 28 |
| 16 | 3 | 1 | 2 | 0 | 1 | 2 | 9 |
| 19-A | 10 | 20 | 5 | 0 | 0 | 2 | 37 |
| 19-B | 2 | 1 | 2 | 0 | 0 | 0 | 5 |
| 20-A | 8 | 2 | 5 | 0 | 0 | 1 | 16 |
| 20-B | 17 | 22 | 5 | 1 | 2 | 3 | 50 |
| Whole sites | 32 | 46 | 25 | 2 | 6 | 7 | 118 |

Notes : Division
① Annelida
② Mollusca
③ Arthropoda
④ Echinodermata
⑤ Prochordata

(b) Composition by Division

The composition by division of benthos is tabulated in Table 3.8.14. There was a difference in the composition by division among the sites. At Site 4, Site 5-C, Site 8 and Site 20-B in the channels, Annelida accounted for 43.3 to 51.1%, and at Site 9-A, Site 13, Site 14 and Site 19-A, Mollusca for 65.8 to 91.5%, while at Site 1-A near the sea water intake facilities of Umm Al Nar Station, Arthropoda accounted for 67.9%.

Table 3.8.14: Division Composition of Benthos in Second Survey (Sampling in October, 1988)

| Division / Site | Annelida | Mollusca | Arthropoda |
|---|---|---|---|
| 1-A | 28.3% | 3.8% | 67.9% |
| 4 | 43.3% | 42.5% | 3.9% |
| 5-C | 50.0% | 19.7% | 24.6% |
| 7 | 34.3% | 29.6% | 13.9% |
| 8 | 51.1% | 40.0% | 4.4% |
| 9-A | 1.8% | 91.5% | 6.0% |
| 13 | 14.8% | 80.0% | 4.9% |
| 14 | 16.4% | 75.8% | 2.3% |
| 19-A | 32.3% | 65.8% | 1.6% |
| 20-B | 44.3% | 41.2% | 4.1% |
| All sites | 29.8% | 51.3% | 14.5% |

Remarks : The occurrence individuals was more than 100 individuals/0.15m² at above shown each site.

(c) Main Kinds

The occurrence results of main kinds of benthos are as shown in Table 3.8.15.

Of all the occurrence kinds, ten kinds shown in the above table had a relatively large number of individuals. They were Polychaeta of Annelida, Gastropoda and Bivalvia of Mollusca and Amphipoda of Arthropoda.

Of these, *Ophelina* sp. of Polychaeta had a tendency of increasing at the sites near the sea water intake facilities of Umm Al Nar Station, 54 individuals/0.15 m² appearing at Site 1-A. Also, Capitellidae were found in relatively large quantities in Bateen Channel, 58 individuals/0.15 m² appearing at Site 19-A. Cerithiidae of Gastropoda were predominant, 101 to 256 individuals/0.15 m² appearing at Site 9-A, Site 13 and Site 19-A.

As for Bivalvia, *Pillucina* sp., *Mactra tribus*, *Nitidotellina* ty pes were predominant, but the number of individuals at each site was less than 50 individuals/0.15 m².

Of Amphipoda, *Grandidierella* sp. showed a relatively dense distribution as 144 individuals/0.15 m² at Site 1-A near the sea water intake facilities of Umm Al Nar Station, but were scarcely seen appearing at the other sites.

Table 3.8.15: Main Occurrence Kinds of Benthos in Second Field Survey (Sampling in October, 1988)

| Site \ Kinds | ① | ② | ③ | ④ | ⑤ | ⑥ | ⑦ | ⑧ | ⑨ | ⑩ |
|---|---|---|---|---|---|---|---|---|---|---|
| 1-A | | 1 | 54 | 3 | | | | | 5 | 144 |
| 1-B | 1 | 2 | 3 | | | | | | 4 | 9 |
| 1-C | | | 22 | | | | | | | 12 |
| 4 | 11 | 14 | | | 10 | 45 | | | 1 | |
| 5-A | 13 | 1 | | 3 | 1 | 3 | | | | |
| 5-B | 12 | | | 1 | | | | | | |
| 5-C | 1 | 1 | 1 | 29 | | 23 | | | | |
| 7 | 13 | 5 | | | | | | | | 1 |
| 8 | | | | | 15 | 17 | 3 | 7 | 11 | |
| 9-A | | | | | 1 | 223 | | | 7 | |
| 9-B | | | | 1 | | | | 31 | | |
| 12 | | | 2 | | | | | | | |
| 13 | 17 | 3 | | 22 | 3 | 256 | 46 | | 12 | |
| 14 | | 2 | | | 1 | 1 | 7 | 13 | 7 | |
| 15 | | | | 2 | 1 | | | 1 | | |
| 16 | | 31 | 3 | | | | | 4 | | |
| 19-A | | | 2 | | 58 | 101 | 18 | 6 | 48 | |
| 19-B | | | | | | | | 9 | | |
| 20-A | | | | 2 | 12 | 7 | | | | |
| 20-B | | 6 | 10 | 4 | 18 | | | 3 | 4 | |
| All Sites | 68 | 66 | 97 | 67 | 120 | 676 | 75 | 74 | 99 | 166 |

Notes : Typical occurrence kinds Unit : Individuals/0.15 m²

| | | | |
|---|---|---|---|
| ① | : Polychaeta | Nereidae | |
| ② | | *Nephtys* | sp. |
| ③ | | Ophelina | sp. |
| ④ | | Opheliidae | |
| ⑤ | | Capitellidae | |
| ⑥ | Gastropoda | Cerithiidae | |
| ⑦ | Bivalvia | *Pillucina* | sp. |
| ⑧ | | Mactridae | |
| ⑨ | | Nitidotellina | type |
| ⑩ | Crustacea | *Grandidierella* | sp. |

2) Third Field Survey

The composition by division of benthos is shown in Fig. 3.8.11 and the distributions of number of kinds, individuals and biotic index of benthos are shown in Fig. 3.8.12.

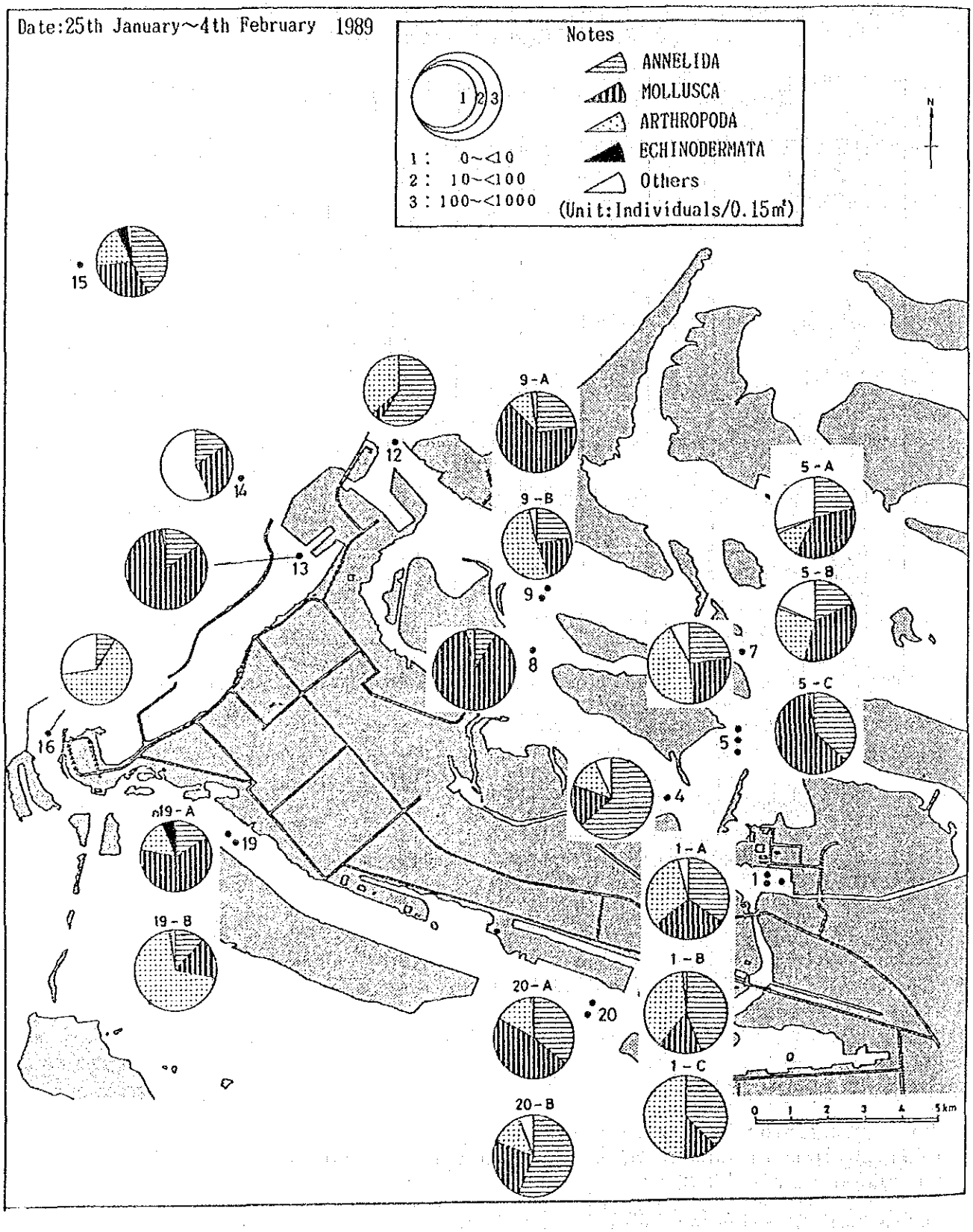



Fig. 3.8.11: Division Composition Distribution of Benthos in Third Field Survey

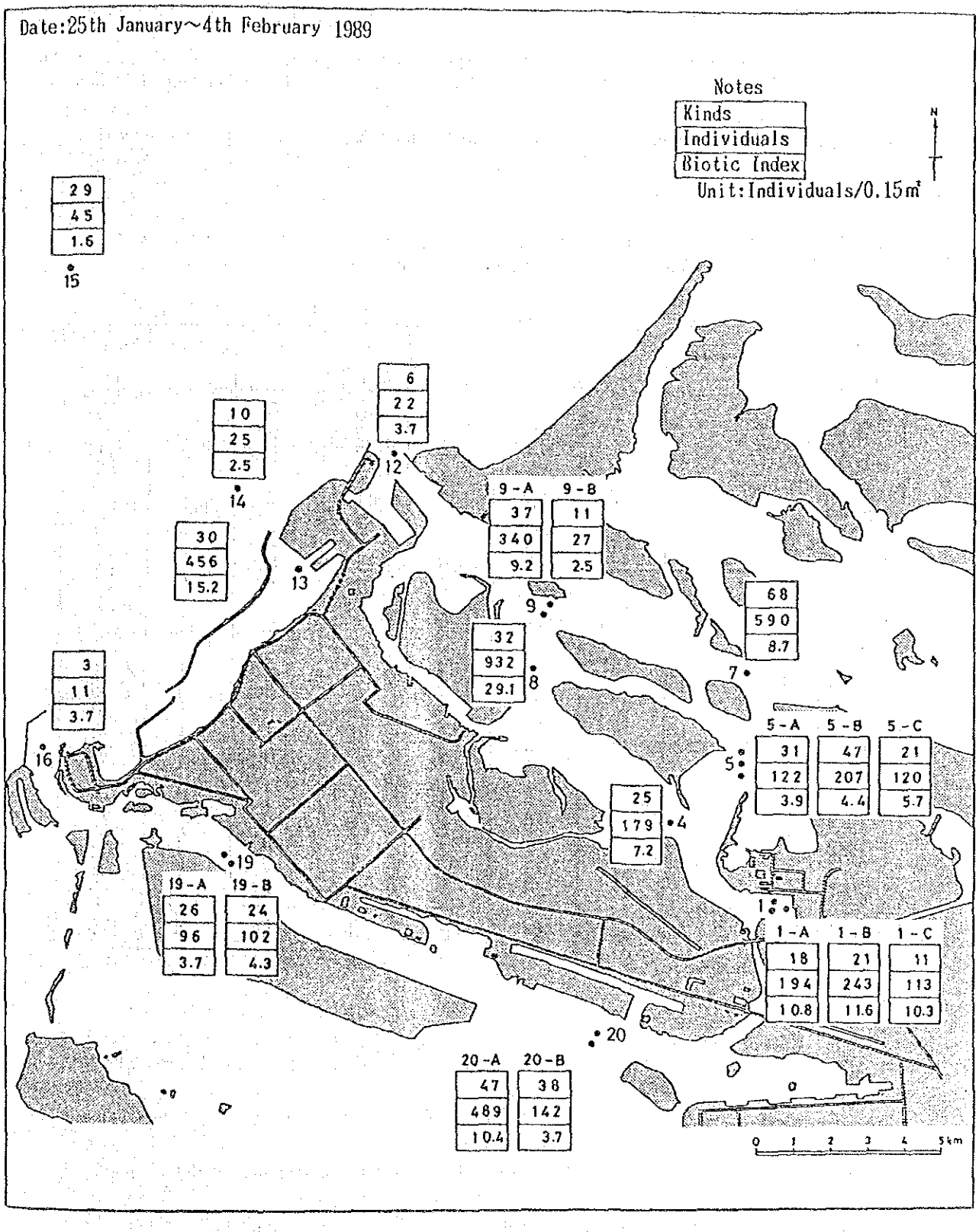



Fig. 3.8.12: Distribution of Kinds, Individuals and Biotic Index of Benthos in Third Field Survey

(a) Number of Kinds

The number of occurrence kinds of benthos is as shown in Table 3.8.16. In the total number of occurrence kinds at all the sites altogether, Annelida, Mollusca and Arthropoda were predominant among all the divisions. Also, the average number of kinds was 27 kinds, and the number of occurrence kinds at each site was greater at Site 5-B, Site 7, Site 9-A, Site 20-A and Site 20-B in the channels.

Table 3.8.16: Occurrence Kinds of Benthos in Third Field Survey (Sampling in February, 1989)

| Site \ Division | ① | ② | ③ | ④ | ⑤ | Others | Total |
|---|---|---|---|---|---|---|---|
| 1-A | 7 | 6 | 4 | 0 | 0 | 1 | 18 |
| 1-B | 8 | 7 | 5 | 0 | 0 | 1 | 21 |
| 1-C | 3 | 3 | 5 | 0 | 0 | 0 | 11 |
| 4 | 12 | 3 | 7 | 0 | 0 | 3 | 25 |
| 5-A | 12 | 13 | 2 | 1 | 2 | 1 | 31 |
| 5-B | 14 | 18 | 8 | 2 | 3 | 2 | 47 |
| 5-C | 12 | 6 | 0 | 1 | 0 | 2 | 21 |
| 7 | 18 | 21 | 20 | 1 | 4 | 4 | 68 |
| 8 | 12 | 14 | 4 | 1 | 0 | 1 | 32 |
| 9-A | 12 | 14 | 8 | 1 | 1 | 1 | 37 |
| 9-B | 6 | 3 | 1 | 0 | 0 | 1 | 11 |
| 12 | 3 | 1 | 2 | 0 | 0 | 0 | 6 |
| 13 | 16 | 11 | 2 | 0 | 0 | 1 | 30 |
| 14 | 3 | 5 | 0 | 0 | 1 | 1 | 10 |
| 15 | 10 | 9 | 9 | 1 | 0 | 1 | 29 |
| 16 | 1 | 0 | 1 | 0 | 1 | 0 | 3 |
| 19-A | 8 | 10 | 6 | 1 | 0 | 1 | 26 |
| 19-B | 5 | 9 | 7 | 1 | 0 | 2 | 24 |
| 20-A | 17 | 14 | 12 | 2 | 0 | 2 | 47 |
| 20-B | 13 | 14 | 5 | 1 | 0 | 5 | 38 |
| Whole sites | 39 | 44 | 35 | 3 | 6 | 8 | 135 |

Notes : Division
① Annelida
② Mollusca
③ Arthropoda
④ Echinodermata
⑤ Prochordata

(b) Composition by Division

The composition by division of benthos is tabulated in Table 3.8.17.

There was a difference in the composition by division among the sites. At Site 4 and Site 20-B in the channels, Annelida accounted for 56.3 to 63.7%, and at Site 5-C, Site 8, Site 9-A and Site 13, Mollusca for 60.8 to 87.8% , while at Site 19-B, Arthropoda accounted for 68.6%.

Table 3.8.17: Division Composition of Benthos in Third Survey
(Sampling in February, 1989)

| Division / Site | Annelida | Mollusca | Arthropoda |
|---|---|---|---|
| 1-A | 34.5% | 29.4% | 32.0% |
| 1-B | 44.0% | 16.9% | 37.4% |
| 1-C | 37.2% | 13.3% | 49.6% |
| 4 | 63.7% | 16.8% | 12.8% |
| 5-A | 21.3% | 36.9% | 10.7% |
| 5-B | 18.4% | 36.2% | 25.6% |
| 5-C | 36.7% | 60.8% | 0.0% |
| 7 | 23.6% | 24.9% | 43.9% |
| 8 | 8.6% | 87.8% | 3.1% |
| 9-A | 23.2% | 64.4% | 9.7% |
| 13 | 15.1% | 83.3% | 0.4% |
| 19-B | 11.8% | 16.7% | 68.6% |
| 20-A | 35.8% | 47.4% | 15.5% |
| 20-B | 56.3% | 24.6% | 12.7% |
| All sites | 25.4% | 51.0% | 18.8% |

Remarks : The occurrence individuals was more than 100 individuals/0.15$m^2$ at above shown each site.

(c) Main Kinds

The occurrence results of main kinds of benthos is shown in Table 3.8.18.

Of all the occurrence kinds, 11 kinds shown in the above table had a relatively large number of individuals. They were Polychaeta of Annelida, Gastropoda and Bivalvia of Mollusca and Tanaidacea and Amphipoda of Arthropoda.

Of these, *Ophelina* sp. of Polychaeta had a tendency of increasing at the sites near the sea water intake facilities of Umm Al Nar Station, 72 individuals/0.15 $m^2$ appearing at Site 1-B. Also, Nereidae appeared at 75 individuals/0.15 $m^2$ at Site 4 in the channel, and Orbiniidae appeared at 47 to 50 individuals/0.15 $m^2$ at Site 8 and Site 20-A, in relatively large quantities.

Table 3.8.18: Main Occurrence Kinds of Benthos in Third Field Survey (Sampling in February, 1989)

| Site \ Kinds | ① | ② | ③ | ④ | ⑤ | ⑥ | ⑦ | ⑧ | ⑨ | ⑩ | ⑪ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1-A | 1 | 13 | 2 | 43 | 3 | 40 | | 11 | 11 | | 32 |
| 1-B | | 19 | 2 | 72 | | 22 | 1 | 12 | 44 | | 26 |
| 1-C | | 11 | 1 | 30 | | 6 | | 8 | 30 | | 20 |
| 4 | 75 | 2 | 2 | 2 | 20 | | | 2 | 2 | 3 | |
| 5-A | 1 | 4 | 2 | 2 | 10 | | | 6 | 2 | | |
| 5-B | 1 | | 1 | | 2 | | | | 5 | 3 | |
| 5-C | 14 | 2 | 3 | 3 | 65 | 1 | | 3 | | | |
| 7 | 7 | | 8 | | 6 | | | | | 57 | |
| 8 | 13 | | 50 | | 776 | 5 | 5 | 15 | | 1 | |
| 9-A | 3 | 29 | 16 | | 150 | | 2 | 45 | | 2 | |
| 9-B | | | 1 | 1 | | 1 | | | | | |
| 12 | | | | 11 | | | | | | | |
| 13 | 2 | 13 | 24 | | 334 | | | 16 | | | |
| 14 | | | 2 | 1 | | | | | | | |
| 15 | | | 3 | | | | 1 | | | | |
| 16 | | | | | | | | | | | |
| 19-A | | 5 | 1 | | | | 14 | 23 | 7 | 2 | |
| 19-B | 1 | | | | 1 | 5 | | | 40 | 22 | 4 |
| 20-A | 1 | 33 | 47 | 16 | | 2 | 65 | 101 | 19 | 15 | 5 |
| 20-B | 1 | 7 | 29 | 2 | | | 3 | | 6 | | 3 |
| All Site | 120 | 138 | 194 | 183 | 1367 | 82 | 91 | 242 | 166 | 105 | 90 |

Notes : Typical occurrence kinds — Unit : Individuals/0.15 m²

| | | | |
|---|---|---|---|
| ① | Polychaeta | Nereidae | |
| ② | | *Nephtys* | sp. |
| ③ | | Orbiniidae | |
| ④ | | *Ophelina* | sp. |
| ⑤ | Gastropoda | Cerithiidae | |
| ⑥ | Bivalvia | Urgulinidae | |
| ⑦ | | *Pillucina* | sp. |
| ⑧ | | *Nitidotellina* | type |
| ⑨ | Tanaidacea | Apseudidae | |
| ⑩ | Crustacea | *Ampelisca* | spp. |
| ⑪ | | *Grandidierella* | sp. |

Cerithiidae of Gastropoda were predominant, 334 to 778 individuals/0.15 m² appearing at Site 8 and Site 13.

As for Bivalvia, Urgulinidae were found in greater quantities at the sites near the sea water intake facilities of Umm Al Nar Station, as compared with the other sites, 22 to 40 individuals/0.15 m² appearing at Site 1-A and Site 1-B. Also, both *Pillucina* sp. and *Nitidotellina* type were predominant at Site 20-A, respectively 65 individuals/0.15 m² and 101 individuals/0.15 m² appearing.

Apseudes of Tanaidacea and *Grandidierella* sp. of Amphipoda had a tendency of increasing at the sites near the sea water intake facilities of Umm Al Nar Station. On the other hand, *Ampelisca* sp. was not found appearing at the sites near the sea water intake facilities of Umm Al Nar Station, but appeared in quantities at 57 individuals/0.15 $m^2$ at Site 7 in Baghal Channel.

(6) Summary

1) Features in Sea around Abu Dhabi Island

(a) Both the second field survey in summer and the third field survey in winter revealed greater number of occurrence kinds of Annelida, Mollusca and Anthropoda as compared with the other divisions. Also, no large seasonal variation was found in the total number of occurrence kinds at all the sites.

(b) Both in summer and in winter, the composition by division of benthos was almost equal on an average at all the sites, Mollusca accounting for 51%, Annelida for 25 to 30% , and Arthropoda for 15 to 19%, respectively.

(c) As for the distribution conditions of the main kinds, a comparatively distinct tendency was found at the sites near the sea water intake facilities of Umm Al Nar Station, where both in summer and in winter, *Ophelina* sp. of Polychaeta, Apseudes of Tanaidacea and *Grandidierella* sp. of Amphipoda were dominant, with *Urgulinidae* of Bivalvia added to them in winter.

2) Benthos as Environmental Index

Benthos have a smaller migrating capacity, as compared with plankton or Pisces, and their distribution and occurrence quantities are determined by propagation and mortality in their respective localities, well reflecting the environmental conditions in each particular site. Also, Polychaeta and Bivalvia, among benthos, and some species of Crustacea are being fixed as index species indicative of their growing environment in numerous survey cases.

Generally speaking, the number of species decreases as the sea pollution advances, giving birth to a tendency for only some determined species to predominate. As a species which lives in high density in areas of organic pollution or day-to-day oil contaminated zones, *Capitella capitata* (species of Capitellidae) is known worldwide.

Hereafter, it is considered necessary to give special attention to any abnormal propagation of these Capitellidae, as well as to the variation in the occurrence quantities of dominant species (*Ophelina* sp. of Polychaeta, *Grandidierella* sp., among the fellow members of Amphipoda, these are considered able to withstand considerable pollution).

3.8.3 Coastal Organism

(1) Purpose

The purpose of coastal organism observation is to clarify the distribution conditions of coastal organisms at typical locations around the Abu Dhabi Island.

(2) Observation Location

The observation locations are as shown in Fig. 3.8.13. 4 locations were selected in the localities which would represent the conditions of the adherent base and biota in the coastal zone around the Abu Dhabi Island.

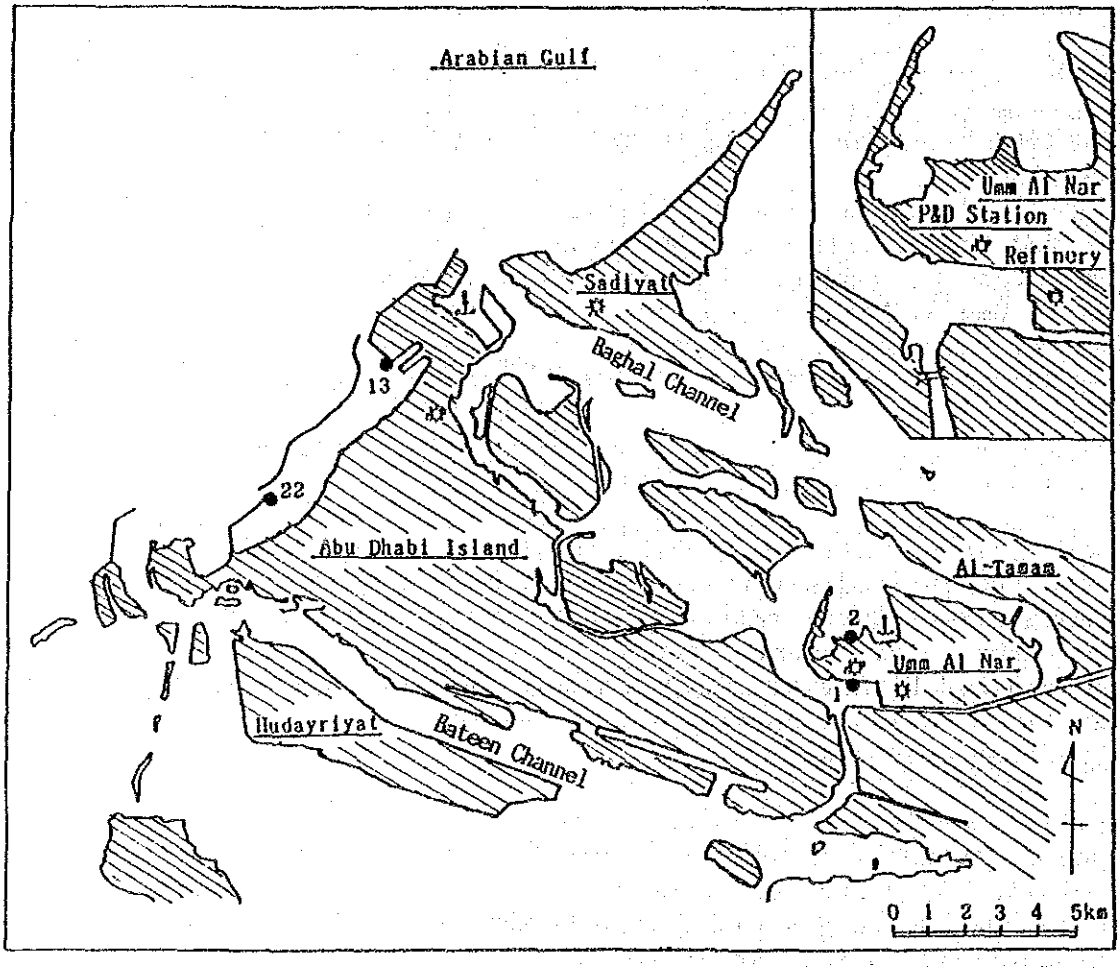



Fig. 3.8.13: Observation Location of Coastal Organism

(3) Duration of Observation

The duration of observation is as follows :

1) Second Field Survey

October 9 to 12, 1988

2) Third Field Survey

February 12 to 15, 1989

(4) Method of Observation

The coastal organisms were observed by the Belt-Transect Method as shown in Fig. 3.8.14. Guide ropes were roped off from the supralittoral zone to the shore line and the quadrate was gradually moved along the ropes. The individuals number or the covering rate of the organisms which were observed in the quadrate, were recorded.

(5) Results

1) Second Field Survey

The occurrence results of coastal organisms are as shown in Table 3.8.19.

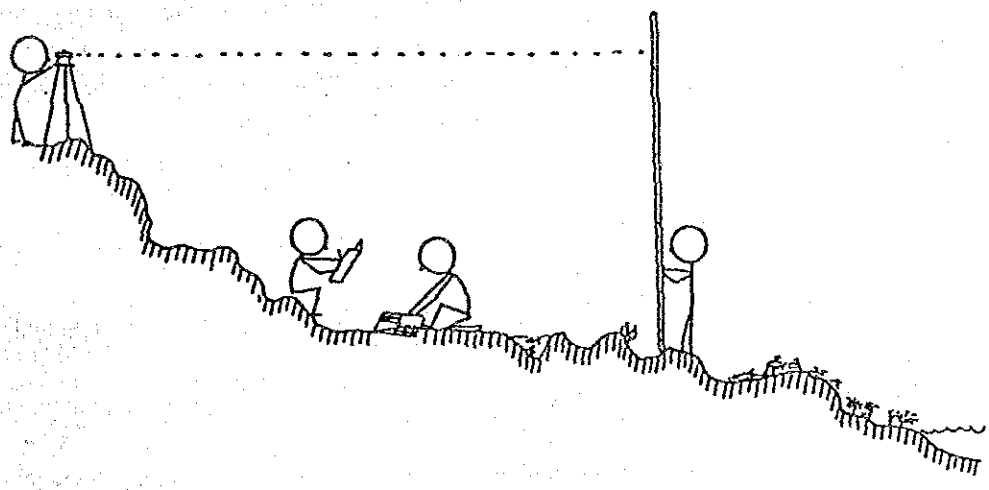


Fig. 3.8.14: Sketch of Coastal Organism Observation

(a) Number of Kinds

The number of occurrence kinds at each of the sites is 4 to 13 kinds, the smallest number occurring at Site 2 near the brine discharge facilities of Umm Al Nar Station. There was not much difference found in the number of occurrence kinds among the sites, except at Site 2.

(b) Main Kinds

Representative kinds included Pom.*Pomatoleios kraussii* of Nereidae, Littorinidae, *Planaxis sulcatus* and *Siphonaria* sp. of Gastropoda, *Isognomon* sp. of Bivalvia, Chthamalidae and *Balanus amphitrite* of Acorn Barnacles, etc.

(c) Distribution

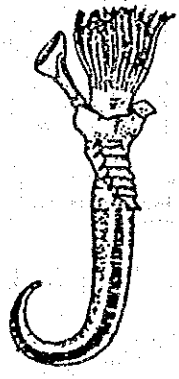
At Site 1 nearby the sea water intake facilities of Umm Al Nar Station, zoning consisting of Chthamalidae, *Balanus amphitrite* * and *Pomatoleios kraussii* ** was observed. At Site 2 near the brine discharge facilities of Umm Al Nar Station, the biota was simple, dominated by *Planaxis sulcatus*.

In the open sea, Chthamalidae dominated above the M. S. L. and *Siphonaria* a sp dominated below the level. At Site 22, *Monodonta dama* besides the above mentioned 2 kinds, were conspicuous.

Notes: * A species of tube worms. It is 15 to 35 mm long and has a calcareous tube of dark blue color. Distributed in Japan, South Africa, the Indian Ocean, Australia, etc.

** A species of acorn barnacles. 15 to 25 mm in diameter and 7 to 12 mm in height. Its shell is white with dark purple stripes. Distributed in the Indian Ocean, the Pacific, the Mediterranean, the Black Sea and a part of the Atlantic Ocean.

*Balanus amphitrite*



*Pomatoleios kraussii*

Table 3.8.19: Occurrence Kinds of Coastal Organism in Second Field Survey

Date:9th~12nd October 1988

| No. | Kind | Site | 1 | 2 | 13 | 22 |
|---|---|---|---|---|---|---|
| 1 | Porifera | *Halichondria* sp. | ○ | | | |
| 2 | Polychaeta | *Pomatoleios kraussii* | ○ | | ○ | ○ |
| 3 | Gastropoda | *Tectus* sp. | ○ | | ○ | |
| 4 | | *Monodonta dama* | | | | ○ |
| 5 | | *Monilea* sp. | | | ○ | |
| 6 | | *Peasuekka roepstiruffuaba* | ○ | ○ | | ○ |
| 7 | | Littorinidae | ○ | ○ | | ○ |
| 8 | | *Planaxis sulcatus* | ○ | ○ | ○ | ○ |
| 9 | | Muricidae | | | | ○ |
| 10 | | *Siphonaria* sp. | ○ | | ○ | ○ |
| 11 | Bivalvia | Mytilidae | ○ | | | |
| 12 | | *Isognomon* sp. | ○ | | ○ | ○ |
| 13 | Crustacea | *Chthamalus* sp. | ○ | ○ | ○ | ○ |
| 14 | | *Balanus amphitrite* | ○ | | ○ | ○ |
| 15 | Urochorda | ASCIDIACEA (group) | ○ | | | |
| 16 | Cyanophyceae | Cyanophyceae | ○ | | ○ | |
| 17 | Chlorophyceae | *Entermorpha* sp. | | | | ○ |
| Total number of species | | | 13 | 4 | 9 | 11 |

2) Third Field Survey

The occurrence results of coastal organisms are as shown in Table 3.8.20.

(a) Number of Kinds

The number of occurrence kinds at each site was 5 to 15 kinds, the smallest number being registered at Site 2 nearby the brine discharge facilities of Umm Al Nar Station. There was not much difference observed in the number of occurrence kinds among the sites, except at Site 2.

(b) Main Kinds

Representative kinds included *Pomatoleios kraussii* of Nereidae, Littorinidae, *Planaxis sulcatus* and *Siphonaria* sp of Gastropoda, *Isognomon* sp. of Bivavia, Chthamalidae and *Balanus amphitrite* of Acorn Barnacles, etc.

(c) Distribution

At Site 1 nearby the sea water intake facilities of Umm Al Nar Station, zoning consisting of Chthamalidae, *Balanus amphitrite krausii* and *Pomatoleios* was observed. At Site 2 nearby the brine discharge facilities of Umm Al Nar Station, the biota was simple, dominated by Littorinidae in the upper part and by *Planaxis sulcatus* in the lower part.

In the open sea, Chthamalidae dominated above the M.S.L. and *Balanus amphitrite* and *Siphonaria* sp. dominated below the level.

Table 3.8.20: Occurrence Kinds of Coastal Organism in Third Field Survey

Date:12nd~15th February 1989

| No | Kind | Site | 1 | 2 | 13 | 22 |
|---|---|---|---|---|---|---|
| 1 | Porifera | *Halichondria* sp. | ○ | | | |
| 2 | Polychaeta | *Pomatoleios Kraussii* | ○ | | ○ | ○ |
| 3 | Gastropoda | *Cellana radiata* | | | | ○ |
| 4 | | *Tectus* sp. | ○ | | ○ | |
| 5 | | *Peasuekka reepstoriffiana* | ○ | ○ | ○ | ○ |
| 6 | | Littorinidae | ○ | ○ | ○ | ○ |
| 7 | | *Planaxis sulcatus* | ○ | ○ | | |
| 8 | | Muricidae | | | | ○ |
| 9 | | *Siphonaria* sp. | | | ○ | ○ |
| 10 | | Doridacea | ○ | | | |
| 11 | Bivalvia | Arcidae | ○ | | | |
| 12 | | Mytilidae | ○ | | | |
| 13 | | *Isognomon* sp. | ○ | | ○ | ○ |
| 14 | | Pteridae | | | | ○ |
| 15 | | Chamidae | | | | ○ |
| 16 | Crustacea | *Chthamalus* sp. | ○ | ○ | ○ | ○ |
| 17 | | *Balanus amphitrite* | ○ | | ○ | ○ |
| 18 | Asteroidea | Asterinidae | | | | ○ |
| 19 | Urochorda | ASCIDIACEA(group) | ○ | | | |
| 20 | Cyanophyceae | Cyanophyceae | ○ | | ○ | |
| 21 | Chlorophyceae | *Entermorpha* sp. | ○ | ○ | ○ | ○ |
| Total number of species | | | 15 | 5 | 10 | 13 |

(6) Summary

1) Features in Sea around Abu Dhabi Island

(a) Both the second field survey in summer and the third field survey in winter revealed a greater number of occurrence kinds of snails (Gastropoda), with not much seasonal variation observed in the total number of occurrence kinds at all the sites.

(b) Slight variation was perceived in the occurrence quantities of some species. In winter, individuals of Littorinidae and *Peasiella roepstorffiana* ıa were a little more numerous than in summer. At Site 22, individuals of *Monodonta dama* were found to have decreased.

(c) The basic distribution pattern through all the sites consisted of Littornidae, Chthamalidae and *Isognomon* sp. in the upper part of the tidal zone, and *Balanus amphitrite*, *Pomatoleios kraussii* and *Siphonaria* genus in the lower part of the tidal zone, but a slight divergency was observed in the composition of the kinds in the vicinity of Umm Al Nar Station and in zones outside the channels.

2) Coastal Organism as Environmental Index

The tidal zone is constantly and repeatedly drying and flooding with tides, and organisms living in the tidal zone are "Zoning" according to their differences regarding morphological and physiological resistance to various environmental conditions.

On the intake side of Umm Al Nar Station, a well-defined Zoning by Chthamalidae, Ba *Balanus amphitriyte* and Poı *Pomatoleios kraussii* were observed. It has been proved by experiment that generally, even those varieties whose adults have a high resistance to oil pollution are vulnerable to it during the stage when they are floating larvae.

Hereafter, it is considered essential to keep an eye on any variations in the attaching quantities and attaching seasons of the above mentioned dominant kinds through immersion tests using attaching boards, or any other means.

## 3.9 Consideration

### 3.9.1 Results of Marine Field Survey

An ecosystem relates to all of the biological and abiological (geological, physical, and chemical) objects and also consists of mutual interference which is very strongly complicated by the conditions which relate one to the other. The oceanic environment is under the influence of precipitation on the coast, tidal action, ocean current, or meteorological action and also, accumulation and distribution in the environment is always balanced by the adjacent water mass, or exchanges of material for sediment and atmosphere.

The coastal hydrosphere is a complex and changeable ecosystem in many ways. The material which is carried from the land is very changeable with regards to quality-quantity, and sometimes shows seasonal variation which has a biologically important meaning.

The characteristics of each hydrosphere consist of composition, acting force, process and so on. Some of those are light or extremely light and others are strong and permanent. When 1 of the forces or processes varies, a new balance is produced in the hydrosphere.

Each ecosystem adapts itself to a particular environment for a long time and consists of biota and society suitable for the environment. Environmental variation as complete and rapid as pollution causes, eliminates particular biology or rapidly increases other biology, and so decreases the value of the ecosystem for marine utilization or amusement.

When a system falls under the influence of hazardous pollutants for the first time, the very sensitive species decrease or only resistant species survive and so the system becomes simple. In the case of the system already being polluted, then the society collapses even if only under pollution of a relatively light level.

(1) Marine Conditions around Abu Dhabi Island

Umm Al Nar Station is located in the lagoon, 25 km south east of Abu Dhabi City. Sea water from Arabian Gulf is supplied to the sea water intake facilities of the station through several channels in the lagoon. These channels have the feature of shallow water depth and narrow channel width.

1) Tidal Level

As shown in Fig. 3.3.4 and Fig. 3.3.5, the variation of tidal level showed principally the semi-diurnal periodicity, but the apparent diurnal periodicity was also recorded.

According to the harmonic analysis results, 4 principal component tides of $M_2$, $S_2$, $K_1$ and $O_1$ occupied the larger part of all amplitudes at all the sites and the sum of the 4 principal component tides was about 100 cm. The value of the classification function of tidal types was respectively 1.09 at Site 1, 1.33 at Site 10 and 1.30 at Site 18. Therefore, the tidal types were mixed tidal type at Site 1 and diurnal type at Site 10 and Site 18.

The water level difference between Umm Al Nar and Mina Zayed was in the range of +66 cm (Umm Al Nar is higher) to -41 cm (Mina Zayed is higher).

2) Tidal Currents

The marine area around the Abu Dhabi Island was classified as being a strong current zone in Baghal Channel and Bateen Channel, a middle current zone offshore of the Abu Dhabi Island, and a slight current zone in Umm Al Nar South Basin. Because of the geographical factor that Baghal Channel and Bateen Channel have the feature of being of shallow water depth and narrow channel width, tidal current speed in both the channels was very high at 90 to 100 cm/s at the strongest current time, and tidal current direction was parallel to each channel.

In the offshore area of the Abu Dhabi Island, there was a dominant direction and the tidal currents of 10 to 20 cm/s were the reciprocating currents parallel to the seaside, that is to say, NE-ward or SW-ward. In Umm Al Nar South Basin, the current speed was small at 0 to 10 cm/s and a dominant direction was not found in the tidal currents.

According to the harmonic analysis results, the tidal types were of a mixed type at the sites, except offshore Site 15 where a diurnal type almost like a mixed type, was shown in the summer survey.

According to the prediction of current conditions during the maximum spring period as shown in Fig. 3.2.7, the time of the strongest ebb current, which streams offshore, was 5 to 7 hours after H.H.W.L. at Mina Zayed and was delayed more in the interior of the lagoon.

3) Water Temperature

According to the long-term observations, the maximum (the monthly average being 31.1 °C and the monthly maximum, 34.4 °C) during the whole observation period was recorded in October 1988 and the minimum (the monthly average being 18.8 °C and the minimum, 16.9 °C) was recorded in January 1989. Then the temperature started rising in early February 1989.

The maximum water temperature was recorded at the site near Umm Al Nar Station. The vertical range of water temperature was generally small. That is to say, the formation of a thermocline may be very difficult in the marine area around the Abu Dhabi Island both due to the shallow water depth and to the relatively large current speed.

4) Salinity

The salinity was respectively in the range of 41.42 to 47.22 in the summer survey, and 41.38 to 47.21 in the winter survey, and all the observations showed a salinity greater than 40.

Regarding the horizontal distribution of the salinity, the salinity was found to be lower as one advanced offshore. The diurnal or semi-diurnal variation was shown in the salinity in both the channels and its variation was in the range of 1 to 3.

The vertical range of salinity at each site was generally small in both the summer and the winter surveys. But on the side of the brine discharge facilities of Umm Al Nar Station, the distribution of high temperature and high salinity was found in the lower layer during the ebb tide period. This phenomenon might be caused by the fact that the high temperature and high salinity discharge from Umm Al Nar Station streams north while submerging down to the lower layer.

5) Water Quality

In the neighborhood of Umm Al Nar Station, high distributions of water temperature, salinity, turbidity and TOC were observed. This phenomenon might be caused by the fact that the sea water near Umm Al Nar Station cannot be easily replaced with sea water in the open sea.

6) Bottom Sediment

At the sites near the sea water intake facilities of Umm Al Nar Station, the ratio of bottom sediments below the silty portion was large and the particle size distribution was fine. But in the offshore area of the Abu Dhabi Island and in the neighborhood of the entrance to both the channels, the bottom sediments contained many gravels and were coarse.

The coefficient of correlation between mercury, lead, copper, zinc and TOC and the ratio below of very fine sand was 0.6 or more, showing a tendency for these contents to increase as the particle size distribution became finer.

The level of heavy metals and organic substances in the bottom sediments around the Abu Dhabi Island was low and it can be considered that no remarkable marine pollution is caused by heavy metals and organic matter.

7) Marine Organisms

(a) Phytoplankton (Water Sampling Method)

Both the second field survey in summer and the third field survey in winter revealed a greater number of occurrence kinds of Bacillariophyceae and Dinophyceaeas as compared with the other algae. Also, the number of occurrence kinds at all the sites, seasonally considered, was a little greater in summer.

The average number of occurrence cells, horizontally considered, was smaller around Umm Al Nar Station and greater in the offshore.

The occurrence conditions of dominant kinds differed among the sites and between the tides. But *Leptocylindrus danicus* was predominant in summer and Haptophyceae in winter. Also, signs of marine pollution were not found.

(b) Zooplankton (Water Sampling Method)

Both in summer and in winter, the number of occurrence kinds of Ciliata and Copepoda was predominant. The occurrence conditions of dominant kinds differed according to the seasons. Nauplius larvae of Copepoda were predominant in summer and Oligotrichida prevailed in winter. Also, signs of marine pollution were not found.

(c) Zooplankton (Net Method)

In summer and in winter as well, the number of occurrence kinds of Copepoda was predominant and seasonal variation was not found in the number of occurrence kinds. Nauplius larvae of Copepoda were predominant in summer and winter. Also, signs of marine pollution were not found.

Copepoda and Appendiculata are considered effective as an index of marine pollution.

(d) Benthos

Both the second field survey in summer and the third field survey in winter revealed greater number of occurrence kinds of Annelida, Mollusca and Arthropoda. As for the main kinds near the sea water intake facilities of Umm Al Nar Station, *Ophelina* sp. of Polychaeta, Apseudes of Tanaidacea and *Grandidierella* sp. of Amphipoda were dominant in summer and winter. But these kinds scarcely occurred at the other sites.

Polychaeta and Amphipoda are considered effective as an index of marine pollution.

(e) Coastal Organisms

The basic distribution pattern through all the sites consisted of Littornidae, *Chthamalus* sp. and *Isognomon* sp. in the upper part of the tidal zone, and *Balanus amphitrite*, e, *Pomatoleios kraussii* and *Siphonariagenus*

in the lower part of the tidal zone.

Also, signs of marine pollution were not found.

(2) Decision Factors of Marine Characteristics around Abu Dhabi Island

The following are considered as the main decision factors of marine characteristics around the Abu Dhabi Island:

1) Climatic Conditions

The Abu Dhabi Island is located in a desert climatic zone and the annual atmospheric temperature is in the range of 10 to 45 °C. A little rainfall is found in winter, but no rainfall is found in summer at all. Accordingly, the temperature and salinity of the sea water around the Abu Dhabi Island are high at 18 to 36 °C, and more than 40 respectively.

Also, biota around the island is liable to consist of suitable species for these environmental conditions.

2) Geographical Conditions

The south of the Abu Dhabi Island faces Arabian Gulf and the other 3 parts are close to a lagoon. There are several channels in the lagoon and these channels have the feature of shallow water depth and narrow channel width.

Due to these geographical conditions, streams and returning currents in the channels are strong. Also, because of the very long channels, the apparent delay in variation of tidal elevation and tidal currents is found between the entrance, and the inner part of channels, and the exchange of sea water between the interior of the lagoon and the open sea is not so good.

3) Tidal Force

The annual maximum range of tidal level around the Abu Dhabi Island is relatively large at about 2 m. So, the streams in the channels are very strong.

3.9.2 Periodic Monitoring Method for Marine Pollution at Umm Al Nar Station

The power and desalination plant uses sea water as cooling water and raw sea water. The following points are desirable regarding the water quality of the intake sea water:

(1) Small variation in raw sea water quality
--- Decline in efficiency of power generation and desalination

(2) Exclusion of substances ($NH_4$-N, $H_2S$, so on) which corrode the material of the equipment
--- Corrosion of metal material, shut down of plant operation

(3) Exclusion of substances ($SiO_2$,$CaCO_3$, so on) which produce scale and sediments
--- Decline in efficiency of power generation and desalination, corrosion

(4) Exclusion of substances (oil, dissolved organic matter, so on) which cause bubbling in evaporator and blockage of sand filter
--- Decline in efficiency of power generation and desalination, shut down of plant operation

(5) Exclusion of bad smelling substances (oil, volatile organic matter, so on)
--- Quality decline of product water

(6) Exclusion of sedimentation solid (sand, shell, so on)
--- Erosion of plant material

(7) Exclusion of suspended solid (detritus, silt, so on)
--- Corrosion of metal material

(8) Exclusion of fouling organism larvae (Barnacle, Ascidiacea, so on)
--- Corrosion of metal material, decline in efficiency of power generation and desalination

(9) Exclusion of bacteria which causes slime production
--- Corrosion of metal material, decline in efficiency of power generation and desalination

(10) Exclusion of macro biota (algae, small fish, jelly fish, so on)
--- Blockage of band screen

(11) Exclusion of hazardous substances (heavy metal, agricultural chemicals)
--- Quality decline of product water

Therefore, operation conditions of the power and desalination plant depend very much on the quality of the feed sea water. Accordingly, information on marine characteristics around the Abu Dhabi Island is necessary for operation and maintenance-control of the power and desalination plant.

Based on the decision factors of marine characteristics around the Abu Dhabi Island, the following periodic monitoring method of marine pollution at Umm Al Nar Station is proposed as shown in Table 3.9.1.

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Table 3.9.1: Recommended Items of Survey on Marine Environment

| Items | Water Quality | Bottom Sediment | Zooplankton (Net Method) | Benthos | Coastal Organism |
|---|---|---|---|---|---|
| Site No. | | | | | |
| 1 | ○ | ○ | ○ | ○ | ○ |
| 9 | ○ | ○ | ○ | ○ | – |
| 13 | ○ | ○ | ○ | ○ | ○ |
| 15 | ○ | ○ | ○ | ○ | – |
| 19 | ○ | ○ | ○ | ○ | – |
| 23 | ○ | ○ | – | ○ | – |
| 25 | ○ | ○ | – | ○ | – |
| Observation Layer | * 0.5 m below sea surface<br>* 1.0 m above sea bottom | * Surface of sea bottom | * From 1 m above sea bottom to sea surface | * Surface of sea bottom | |
| Frequency | * Low tide period & high tide period<br>* Every 3 months | * Summer period & winter period | * Low tide period & high tide period<br>* Every 3 months | * Every 3 months | * Every 3 months |
| Observation Items | * Water temp.<br>* Salinity<br>* pH<br>* Dissolved oxygen<br>* Turbidity<br>* TOC<br>* Ammonic nitrogen<br>* Oil content | * Particle size distribution<br>* Specific gravity<br>* TOC<br>* Oil content<br>* Mercury<br>* Copper<br>* Lead<br>* Zinc | * Identification & calculation of Copepoda & Appendiculata | * Identification & calculation of Polychaeta & Amphipoda | * Identification & calculation of kinds |