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## Seasonal Variation of Medusae and Ctenophores in the Innermost Part of Tokyo Bay[1),2)]

In recent years, knowledge has accumulated rapidly on the seasonal variation of zooplankton in Tokyo Bay (ANAKUBO & MURANO 1991, NAGASAWA 1991, NOMURA & MURANO 1992, NOMURA et al. 1992). However, little is known about medusae and ctenophores in the bay. Information on the seasonal occurrence of medusae and ctenophores, which are voracious predators of other zooplankton and fish larvae (ALLDREDGE 1984, MÖLLER 1984, PURCELL 1985), is almost certainly of major importance in attempting to understand the seasonal variation of other zooplankton fauna and their population dynamics in the bay. To the present day, eleven taxa of medusae and ctenophores have been reported to occur in Tokyo Bay; i. e. *Rathkea octopunctata* (M. SARS), *Obelia* spp., *Eucheilota para-doxica* MAYER, *Proboscidactyla flavicirrata* BRANDT, *Aurelia aurita* (LINNÉ), *Chrysaora melanaster* BRANDT, *Spirocodon saltator* (TILESIUS), *Bolinopsis mikado* (MOSER), *Beroë cucumis* FABRICIUS and *Carybdea rastoni* HAACKE (HIRASAKA 1915, KOMAI 1918, SUGIURA 1980, NOMURA & MURANO 1992). Of these, seasonal variation of the first five taxa were reported by SUGIURA (1980), but no infomation exists on the other species. We investigated the seasonal variation of medusae taxa at a station off Funabashi Harbor which we believe to be representative of the innermost part of Tokyo Bay (Figure 1).

From February 1988 to February 1989, a series of samples were collected at five depths

1) Received 5 July, 1993, Accepted 2 June, 1994
2) 東京湾湾奥部におけるクラゲ類の季節変化

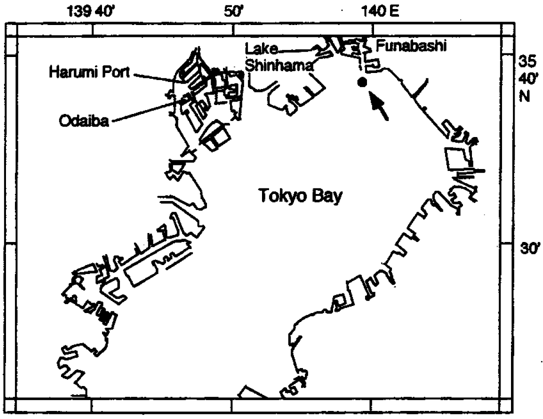


Fig. 1. Location of the sampling station (closed circle) off Funabashi, Tokyo Bay.

0, 2, 4, 6 and 8 m). Five minute horizontal tows at each depth were conducted with a Marukawa closing net (30 cm in diameter with 0.493 mm mesh). The amount of water passing through the net on each tow was measured with a flow-meter placed in the net mouth. The volume of water filtered ranged from 0.92 to 61.5 $m^3$ (mean=13.4, s. d.=9.4, n=102). Samples were fixed in 5 % buffered formalin-seawater and transferred into 70% ethanol. Water temperture and salinity at the five depths were measured with an electronic T-S meter. For more details on sampling procedures and general oceanographic features, see NAGASAWA(1991). In the laboratory all medusae and ctenophores were sorted out from the samples, identified and counted under a dissecting microscope. Nomenclature of hydromedusae follows KRAMP(1961, 1968). For siphonophores, only the number of anterior nectphores was counted. Species abundances in each layer were averaged to obtain the overall mean biomass at each collection.

A total of thirteen taxa were identified, of which three were identified only to the generic level (Table 1). All individuals of *Bougainvillia* sp. were immature, measuring 0.5–1 mm in both height and diameter. *Obelia* spp. could not be identified to the species level as is often the case. Specimens of *Phialidium* sp. were not in good enough condition to make an unequivocal identification. Among the thirteen taxa collected, six species were recorded for the first time in Tokyo Bay. They were *Liriope tetraphylla* (CHAMISSO & EYSENHARDT), *Muggiaea atlantica* CUNNINGHAM,

Table 1. List of medusae and ctenophores occurring at Funabashi, with the total number caught and the date that they occurred. Asterisks indicate the presence of mature medusae in the sample.

| Taxa | Total catch | Date of occurrence |
|---|---|---|
| *Rathkea octopunctata* | 7768 | 13/2/88, 28/3*, 2/12*, 6/1/89, 27/1*, 20/2 |
| *Liriope tetraphylla* | 3972 | 28/3/88, 15/10*, 29/10*, 18/11, 2/12* |
| *Muggiaea atlantica* | 1640 | 10/5/88, 15/10*, 29/10*, 18/11* |
| *Obelia* spp. | 105 | 13/2/88*, 28/4*, 10/5*, 23/6*, 18/8*, 2/9*, 1/10*, 15/10*, 29/10*, 18/11*, 2/12* |
| *Proboscidactyla ornata* | 79 | 13/2/88*, 28/3*, 15/10, 29/10* |
| *Beroë cucumis* | 63 | 29/10/88, 18/11, 2/12, 15/12, 6/1/89, 20/2/89 |
| *Aurelia aurita* | 61 | 13/2/88, 28/3, 14/4, 28/4, 10/5, 29/10, 2/12, 15/12, 6/1/89, 27/1, 20/2 |
| *Phialidium* sp. | 31 | 23/6/88*, 29/10* |
| *Phialidium chengshanense* | 26 | 15/10/88*, 29/10* |
| *Bougainvillia* sp. | 18 | 23/6/88, 2/9 |
| *Podocoryne minima* | 1 | 1/10/88 |
| *Nemopsis dofleini* | 1 | 13/2/88* |
| *Spirocodon saltator* | 1 | 20/2/89* |
| Unidentified hydromedusae | 6 | 14/4/88, 29/10 |

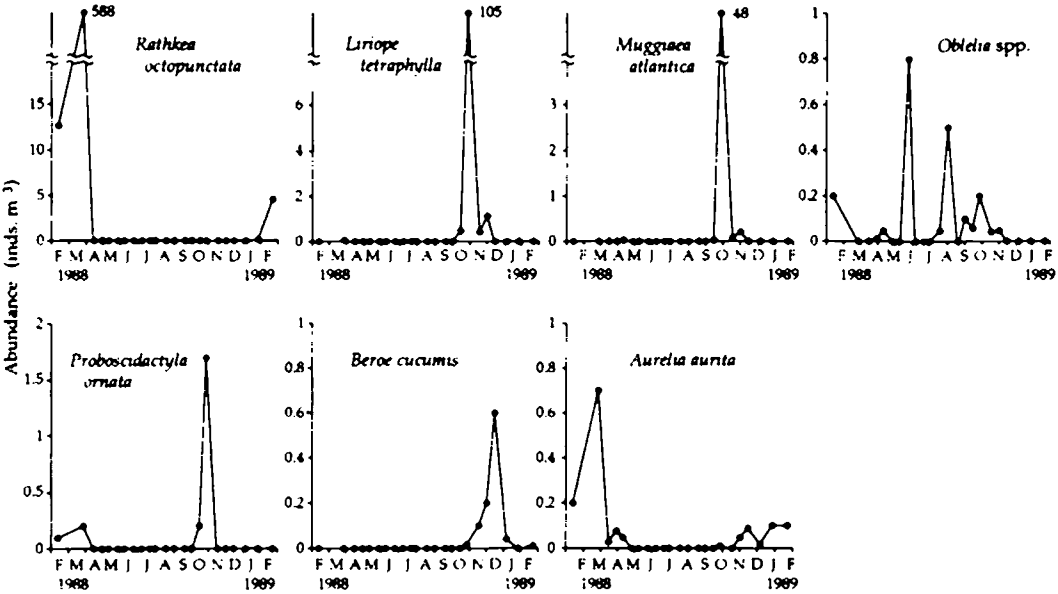


Fig. 2. Seasonal abundance of seven major taxa.

Table 2. The percentages of the mature medusae of *Rathkea octopunctata* with or without medusa-buds, and that of immature medudae with medusa-buds.

| Date | Mature | | | | Immature | | Number of medusae examined |
|---|---|---|---|---|---|---|---|
| | Female | | Male | | | | |
| | with buds | without buds | with buds | without buds | with buds | without buds or manubrium lost | |
| 13 Feb. 1988 | 0% | 0% | 0% | 0% | 92% | 8% | 125 |
| 28 Mar. | 2 | 23 | 2 | 25 | 35 | 13 | 1403 |
| 2 Dec. | 0 | 50 | 0 | 25 | 25 | 0 | 4 |
| 6 Jan. 1989 | 0 | 0 | 0 | 0 | 100 | 0 | 2 |
| 27 Jan. | 0 | 39 | 0 | 6 | 33 | 2 | 18 |
| 20 Feb. | 0 | 0 | 0 | 0 | 96 | 4 | 706 |

*Proboscidactyla ornata* (McCRADY), *Phialidium chengshanense* (LING), *Podocoryne minima* (TRINCI) and *Nemopsis dofleini* MAAS.

*Rathkea octopunctata* dominated the catches in February and March. It reached 588 inds. $m^{-3}$ on 28 March 1988, disappeared entirely in the April of 1988 and was present again in the December of the following winter (Figure 2). Before February, few specimens had mature gonads (Table 2). In March, 52 % of 1403 individuals were mature. Among them, 4 % were also bearing buds. The ratio of males to females was approximately 1:1. The high percentages of mature medusae in December and January were both as a result of analysis of only a small number of mature medusae from only one layer (four individuals from depth 8 m on 2 December 1988 and eight individuals from depth 6 m on 27 January 1989). Bias caused through the retention of medusae on filters during the process of sorting by former researchers on the same samples is suspected.

*Liriope tetraphylla* and *Muggiaea atlantica* both appeared in mid-October and reached their maximum densities at the end of October (Figure 2). From then on, they decreased and almost disappeared from the catches after mid-December. Bracts of the eudoxids of *M. atlantica* appeared as often as anterior

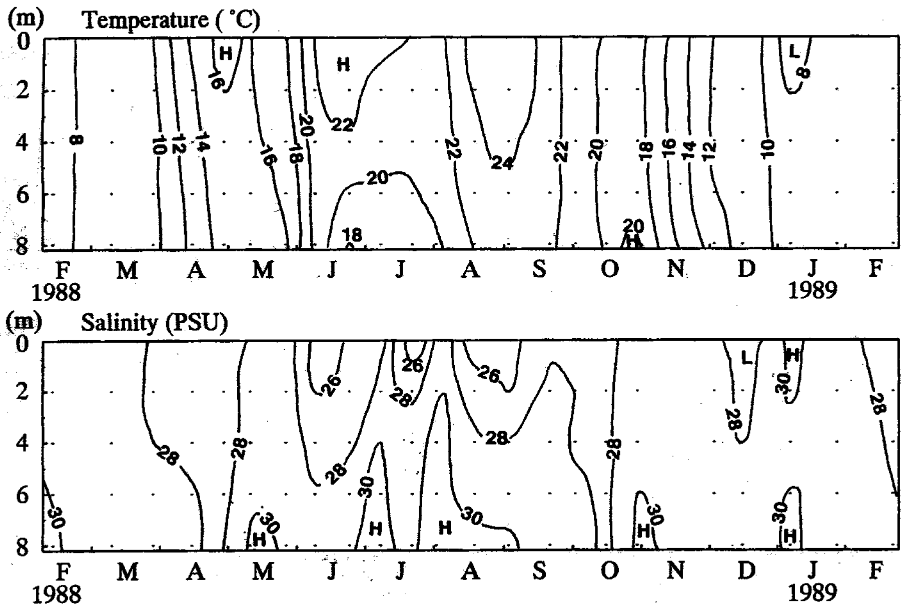


Fig. 3. Water temperature and salinity at the sampling station from 13 February 1988 to 20 February 1989.

nectophores.

*Obelia* spp. occurred occasionally throughout the period of sampling. They were abundant in spring and autumn reaching a maximum of 0.8 inds. $m^{-3}$ on 23 June and a second maximum of 0.5 inds. $m^{-3}$ on 2 September, but were rare in both summer and winter (Figure 2).

*Proboscidactyla ornata* occurred during the autumn to winter period. Their maximum density was 1.7 inds. $m^{-3}$ on 29 October (Figure 2), when immature medusae with medusa-buds were abundant. Immature medusae occurred only in October.

*Beroë cucumis* occurred during the autumn to winter period reaching their maximum density of 0.6 inds. $m^{-3}$ on 15 December 1988 (Figure 2). Whether these individuals were mature or immature could not be determined because of the shrinkage of the specimens.

Ephyrae and young medusae of *Aurelia aurita* occurred during the winter to spring period. They were most abundant on 28 March of 1988 and on 27 January and 20 February of 1989, when they reached 0.7, 0.1 and 0.1 inds. $m^{-3}$ respectively (Figure 2).

*Phialidium chengshanense* occurred only in October. Both polygastric medusae and monogastric medusae, which had three or less radial canals and may therefore be immediately post-fissional, occurred.

*Podocoryne minima*, *Spirocodon saltator* and *Nemopsis dofleini* were each represented by only one individual in this series of samples. *P. minima* was immature and had medusa-buds. Both *N. dofleni* and *S. saltator* had gonads, but their body size was much smaller than that of fully grown medusae.

Among the seven major taxa, *R. octopunctata*, *L. tetraphylla*, *M. atlantica*, *Obelia* spp., *P. ornata* and *B. cucumis* were distributed more densely in the deeper layers than in the shallower layers. This may be caused in part by the fact that sampling was always conducted during the day. In most cases they were more abundant in the 6 m layer than in the 8 m layer. *Aurelia aurita* was rare in the 0 m layer, but was distributed evenly in layers deeper than 2m.

Medusae and ctenophores were abundant both numerically and in taxon number during October to March. This was mainly because of the temporal occurrence of cold water species (*R. octopunctata*, *N. dofleini* and *S. saltator*) and warm water species (*P. chengshanense*, *P. minima*, *P. ornata*, *L. teteraphylla* and *M. atlantica*) (KRAMP 1961, 1968, RUSSELL 1934). Cold water species occurred in winter (from January to March), when the water temperature was under 10 ℃ (Figure 3). Warm water species occurred in autumn (from October to December), when the water column was well mixed and the water temperature was decreasing. The only exception was *P. ornata*, where mature specimens occurred through autumn and winter. In four of the five warm water species (*L. tetraphylla*, *M. atlantica*, *P. ornata* and *P. chengshanense*), nearly all sampled individuals were collected on 29 October. They occurred for the first time on 15 October. One of these species, *L. tetraphylla*, is oceanic. An oceanic chaetognath species, *Sagitta enflata* GRASSI, was also present on 15 and 29 October in the same samples (NAGASAWA 1991, NAGASAWA pers. comm.). Summer stratifica-tion ended in September, and on 15 October the salinity was homogeneous throughout the water column (Figure 3). On 29 October, both the temperature and salinity were high in the bottom layer suggesting an inflow of oceanic water through the bottom layer. Water from the inner bay has been shown to flow out to sea through the surface layers and oceanic water to inflow through the bottom layer during September through May in Tokyo Bay (HASUNUMA 1979). The warm water species we observed were probably advected from the southern part of the bay or out of the bay by just such a vertical circulation of water in the bay.

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