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# Nutrients in Koshikijima deep seawater

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**Abstract**

Nutrient concentrations in Koshikijima deep seawater pumped from a depth of 375 m were examined from July 2003 to June 2004. Nutrients were variable and showed marked increases and decreases in a short period. However, average monthly concentrations of nitrate, phosphate, and silicate showed that there is some parallelism in the variation of nutrients. Mean N/P ratio (15) in the present study was close to the Redfield ratio of 16 observed in the open water. As sample water was taken significantly deeper than euphotic layer in the East China Sea, no chlorophyll was detected throughout the year. Dissolved organic nitrogen (DON) was at the level of oceanic surface water. It was concluded that Koshikijima deep seawater has the properties of open water in that it is less influenced by artificial factors.

**Key words** :deep seawater, nutrients, Koshikijima

## Introduction

Low temperature, high nutrients, and low bacteria generally characterize seawater at depths below 200 m. With these advantages of deep sea water, technologies for the use of deep seawater in agriculture, fisheries, and thermal energy have been developed. In Japan, the Kochi and Toyama Prefectures were the first to establish pumping systems for deep seawater from a depth of 300 m and apply the water to uses in industry. In Kagoshima Prefecture, a private company Koshiki Deep Ocean Water Co., Ltd. in Koshikijima Island installed a deep seawater pumping system in 2003. The Island is located in west 50 km from Satuma Peninsular in the East China Sea. The depth of intake is 375 m depth and the length from the shore is about 4 km. The daily intake of deep seawater is 400 ton. Currently, the major use of the deep seawater is for beverages. Two kinds of mineral waters are produced from salt removed deep seawater. The purpose of this research is to ascertain the nutrient concentrations in Koshikijima deep seawater.

## Materials and Methods

Koshiki Deep Ocean Water Co., Ltd provided the deep seawater from Koshikijima. The sampling location is shown in Fig. 1. The seawater was sampled every week from June 2003 to July 2004 for this research. The water was bottled and a total of 49 samples were sent to Kagoshima University by a cool delivery service immediately after sampling for this study. The seawater was filtered through two 25 mm Whatman GF/F glass fiber filters. The filters were stored in a deep freezer at −30℃ and each of them was used to analyze chlorophyll and particulate organic carbon and nitrogen. The filtrate was stored in deep freezer at −30℃ until nutrient analysis. Phosphate phosphorus, nitrate nitrogen, nitrite nitrogen, ammonium nitrogen, and silicate silicon were determined as described by Parsons et al. (1984). Dissolved organic nitrogen (DON) was also estimated. To calculate DON concentration, total dissolved nitrogen (TDN) was obtained by a persulfate oxidation method (Solorzano and Sharp, 1980). The

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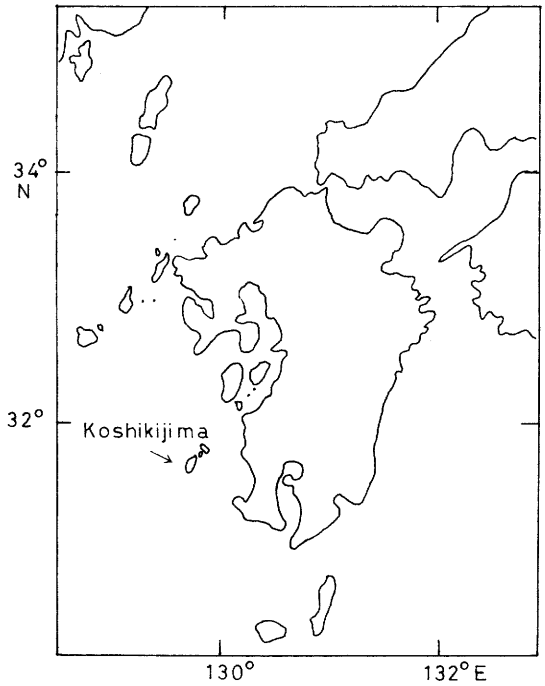


Fig. 1 Location of sampling station.

total of inorganic fractions (nitrate, nitrate, and ammonia) was subtracted from TDN after oxidation and the residual nitrogen defined as DON. Because the deep seawater was taken significantly below the euphotic layer in the East China Sea, it was assumed that there was no living phytoplankton was in the seawater sample. To check this assumption, we measured chlorophyll concentration by a fluorescence method (Parsons et al., 1984) using a Turner TD-700 fluorometer.

## Results and Discussion

Inorganic nitrogen in seawater occurs as ammonia, nitrite, and nitrate. However, ammonia was not detected in most of the samples, and occurred only in April in a range of 0.1 to 0.2μM. Nitrite concentration was also low and less than 0.1 μM in all samples. In contrast, concentrations of nitrate were significantly high and ranged from 14 to 29 μM. The present result shows that the most of the inorganic nitrogen as nutrient in Koshikijima deep seawater was in the form of nitrate. The above nitrogen distribution reflects a typical feature of deep open seawater.

Fig. 2 shows the changes in nitrate concentration. The nitrate concentration was variable and the lowest value (14 μM) was obtained at the 4th week in July, while the highest value (29 μM) was observed at the 3rd week in December. The results do not demonstrate a pattern of a clear seasonal change of nitrate. One of the remarkable features is that nitrate concentration may sharply change within a short period of time. For example, the concentration in July changed quickly from 24 μM to 14 μM in one week and the concentration increased to 24 μM at the 1st week in August. The rapid increase or decrease of nitrate concentration in a short period of time was observed throughout the year.

Fig. 3 shows phosphate concentrations. Phosphate concentration also showed rapid increases and decreases as with nitrate concentration. Most of the measured values were in the range of 1 to 2 μM. Maximum concentration (2.1 μM) was observed in October and the minimum value (0.9 μM) in May. Phosphate concentration at the beginning of July was 1.9 μM. The content rapidly decreased to 1 μM in August. The phosphate concentration suddenly increased to 1.9 μM in September and basically showed a high value of 2 μM until November. Again, while

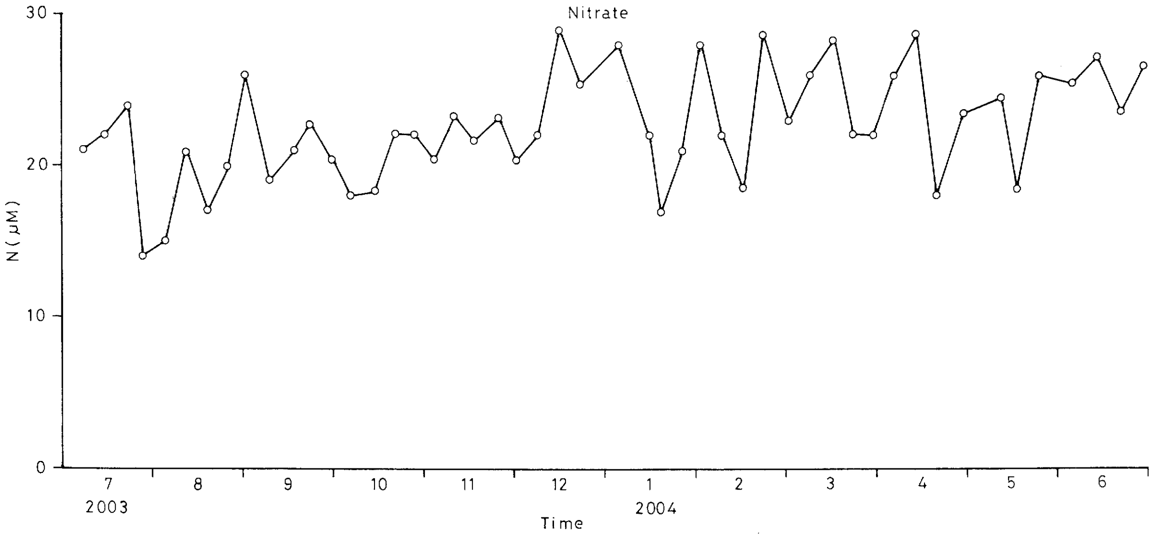


Fig. 2 Weekly variations in nitrate nitrogen concentration.

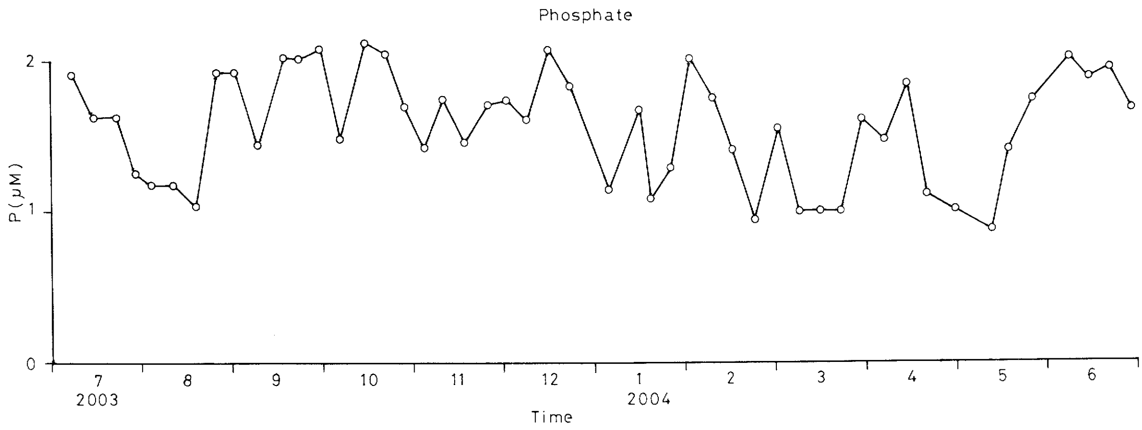


Fig. 3 Weekly variations in phosphate phosphorus concentration.

phosphate concentration fluctuated, no clear seasonal variation was observed.

Fig. 4 shows silicate distributions. The fluctuation of silicate concentration was large and showed an about 8 fold change. The concentration gap for silicate was larger than those for nitrogen and phosphorus. Minimum concentration (14 μM) occurred in July and maximum (94 μM) was observed in June. Low concentrations below 20 μM were measured in summer and early autumn, and high concentrations above 50 μM through the seasons. There was no systematic decrease or increase of silicate concentration.

It is clear that Koshikijima deep seawater has abundant nutrients. Seawater around Koshikijima Island originates from the warm Kuroshio water (Chaen and Ichikawa, 2001). Nutrients in the Kuroshio water in the East China Sea are very low or not detectable in the surface layer above 100 m depth (Ichikawa et al, 1999). Fig. 5 shows vertical profile of nitrate in Kuroshio water off Cape Ashizuri, Shikoku, observed during the Hakuho Maru KH-94-3 cruise in 1994 (Ocean Research Institute, 1995). Koshikijima deep seawater from 375 m depth contains the same level of nitrate as Kuroshio open water at 600 m depth.

Fig. 6 shows average monthly concentrations of nutrients in Koshikijima deep seawater. The trends of increases and decreases of nitrate, phosphate, and silicate showed some parallelism but with some irregularities. The variations of silicate had more contrasts than those for nitrate and phosphate. Silicate in coastal water is easily influenced by many local factors such as river water and engineering works. Seasonal variations in silicate would differ from those

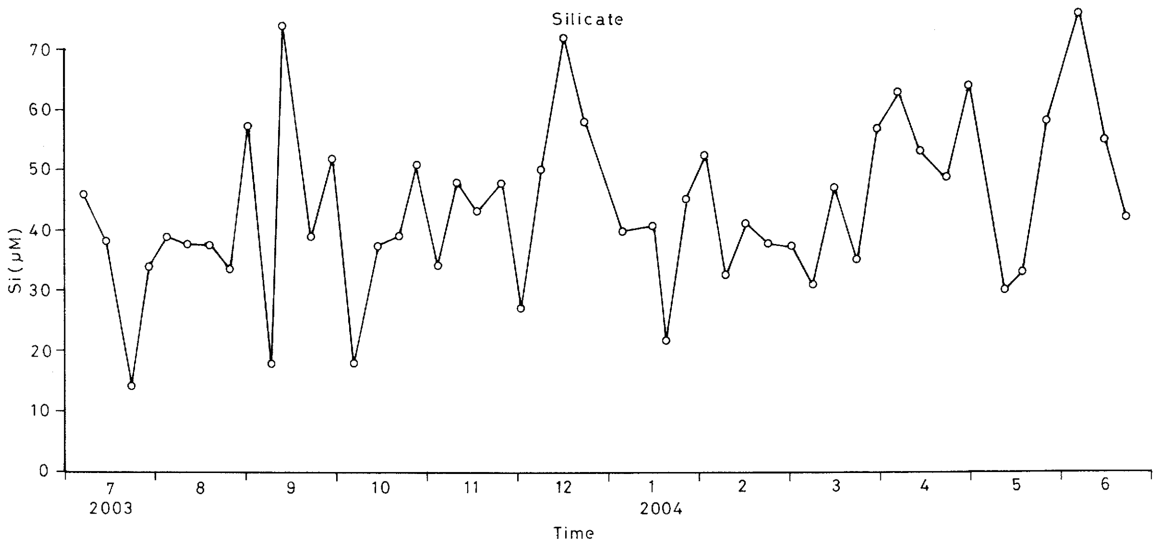


Fig. 4 Weekly variations in silicate silicon concentration.

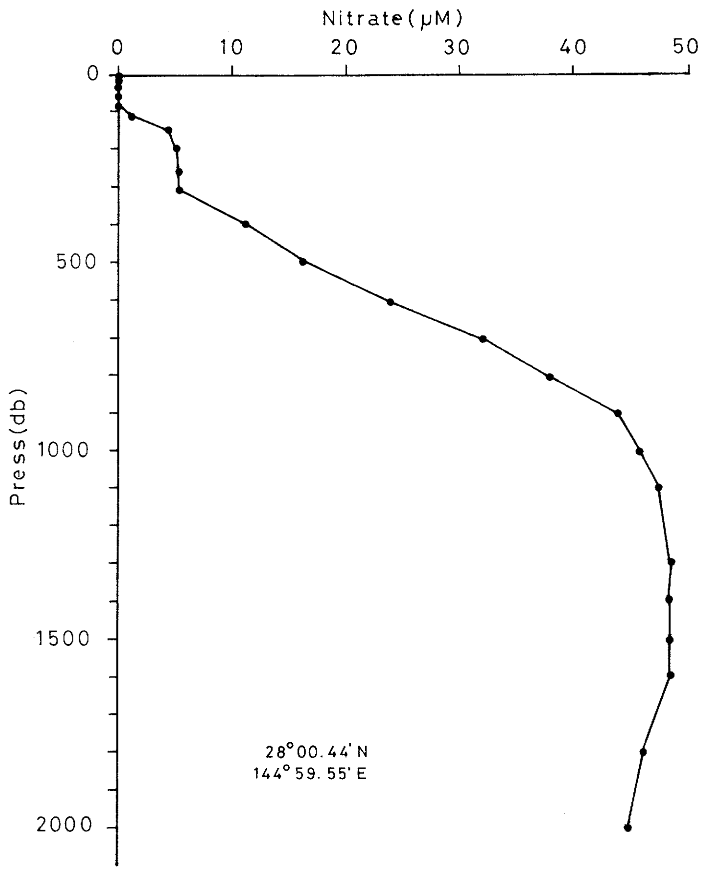


Fig. 5 Vertical profile of nitrate nitrogen concentration in Kuroshio water observed during the Hakuho Maru KH-94-3 cruise in 1994.

of nitrate and phosphate. Redfield et al. (1963) showed that the ratio of N/P in seawater in the world oceans was relatively constant at around 16. This Redfield model assumes that phytoplankton absorb nitrogen and phosphate in the same ratio and nitrogen and phosphate are released in seawater in the same ratio when organic matter is decomposed by bacteria. The calculated N/P ratio in Koshikijima deep seawater ranged from 12 to 20, and the

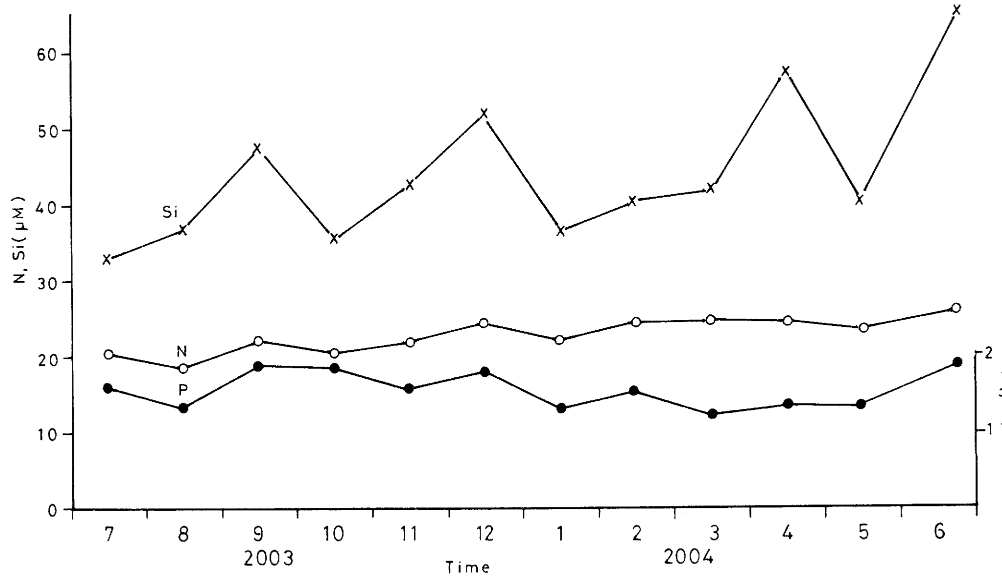


Fig. 6 Average monthly concentrations of nutrients.

average of 15 was close to the Redfield ratio.

No chlorophyll was detected throughout the year because the seawater was sampled below the euphotic layer. Chlorophyll concentration in Kuroshio open water south of Koshikijima Island showed almost zero below 100 m depth (Ichikawa, 2000). Dissolved organic nitrogen (DON) was measured in samples obtained in 2003. DON content in Koshikijima deep seawater was in the range 1 to 8 μM with an average 5 μM. The value was comparable to that of oceanic surface water (Bronk, 2002).

There are many factors that can cause a change of nutrients concentration in seawater. These include terrestrial inputs such as river runoff, rain, vertical mixing, upwelling, and biological processes. We can not evaluate the effect of terrestrial inputs and local precipitation on nutrient changes in water at a depth of 375 m. Ichikawa et al. (2002) showed that nutrient content is a good parameter to describe characteristic water mass in the East China Sea. Because Koshikijima deep seawater has the properties of open water, the physical movement of the water mass may be an important factor causing the variation in nutrient concentrations.

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