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Productivity and abundance of bacteria and phytoplankton in Incheon Dock, western coast of Korea

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Abstract: *The monthly variations of abundance and productivity of bacteria and phytoplankton were investigated in 2002 at Incheon Dock in Korea, almost closed marine ecosystem. Incheon Dock has unique marine environment with scarcely a current and waves such as in a lake. The bacterial abundance was 0.4-6.3 X 10^6 cells·ml^{-1}, while the bacterial productivity showed in the range of 0.7-26.3 mgC m^{-3} hr^{-1}. The phytoplankton chlorophyll-a concentrations fell between 2.1 and 18.1 $\mu g \cdot l^{-1}$, where nanoplankton fractions contributed in 32.5-96.78% (average: 73.2%). The algal bloom occurred in March and August, and primary productivity measured by using ^{14}C method, showed a fluctuation ranging from 49.4 to 4,359.4 mgC m^{-2} day^{-1}. The primary productivity of nanotoplankton accounted for 79% of total phytoplankton. Meanwhile, the ratio of bacterial productivity over primary productivity was between 2.0 and 7.7. This study showed that the abundance and productivity of bacteria and phytoplankton were higher at Incheon Dock than those at other coastal areas in Korea. Especially, the assimilation number was higher at Incheon Dock than that at lake Shihwa which is a severely eutrophicated area. This result indicates that Incheon Dock has unique ecosystem oceanographically and topographically, and it differs from other coastal areas in terms of the low trophic level organisms being abundant and highly productive.*

Key words*: Incheon Dock, Bacteria, Phytoplankton, Abundance, Productivity*
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Introduction

The inner area of Incheon Dock is 1.85x10^7 m^2 and its average water depth is 12 m. Incheon Dock is located in Gyeounggi Bay, western coast of Korea of which the tidal difference is maximum 10 m. This dock is, therefore, a lock gate type dock on which the cargo handling work can be done even at low tides. That is, even if this area is also a marine ecosystem, it has the environmental characters similar to a lake that has little current and wave (Yoo *et al*., 1997). Thus, the biological parameters studied in the research area will be compared with those in other coastal areas in Korea (Cho and Shim, 1992; Lee, 2001; Yang *et al*., 2003; Park and Shin, 2007), as well as in lake Shihwa which is known to be one of the most eutrophicated brackish water environment in Korea (Choi *et al*., 1997). This study is mainly focused on grasping the characters of low trophic level organisms by investigating the abundance and productivity of phytoplankton and bacteria at Incheon Dock in Korea.

Materials and Methods

Biological parameters in Incheon Dock were investigated every month in 2002: its bacterial abundance and productivity were measured at the lock gate area (Station 1) and the old dock area (Station 2), and the phytoplankton chlorophyll-*a* and primary productivity were examined at the lock gate area (Fig. 1). The bacteria and phytoplanktons were collected using van Dorn water sampler, and the phytoplankton sample was filtrated through 20 µm mesh to be classified into total phytoplankton and nanoplankton fraction. The bacterial abundance was measured by using epifluorescence microscopy technique after staining cells with DAPI (Porter and Feig, 1980; Lee and Fuhrman, 1987). The bacterial productivity was measured at a rate by which thymidine incorporates with DNA (Fuhrman and Azam, 1982). Phytoplankton chlorophyll-*a* was measured in accordance with the method used by Parsons *et al*. (1984). The primary productivity of phytoplankton was measured by ^{14}C method (Yoo *et al*., 1992; Park *et al*., 2001).

Results and Discussion

The total bacterial abundance of Incheon Dock ranged from 0.4×10^6 cells ml^{-1} to 6.3×10^6 cells ml^{-1} (Fig. 2A). The average value of the total bacterial abundance was relatively high at the old dock area: 1.8×10^6 cells ml^{-1} at the lock gate area and 2.5×10^6 cells ml^{-1} at the old dock. The monthly bacterial abundance began to increase from March and reached the highest value in June, and then it began to decrease. Meanwhile, lake Shihwa that was environmentally similar to Incheon Dock showed the bacterial abundance ranging 1.4-19.5×10^6 cells ml^{-1}, which was higher than the value obtained from Incheon Dock. The bacterial abundance was, however, higher at Incheon Dock than those at the other coastal areas in Korea but lake Shihwa (Cho *et al*., 1994; Choi *et al*., 1997; Lee *et al*., 1998; Lee, 2001; Yang *et al*., 2003).

The bacterial productivity of Incheon Dock ranged from 0.2 to 3.0 mg C m^{-3} hr^{-1}, and its value was higher in spring and summer than in winter (Fig. 2B). This value was lower than that of lake Shihwa (1.2-38.1 mg C m^{-3} hr^{-1}), which is an eutrophic area, however, higher than that of Yellow Sea (0.003-0.12 mg C m^{-3} hr^{-1}) and other areas (Cho and Shim, 1992; Cho *et al*., 1994; Choi *et al*., 1997; Lee *et al*., 1998). Meanwhile, the bacterial abundance and productivity were higher at the old dock area than at the lock gate area. This result indicates that the bacterial activity is much stronger at the old

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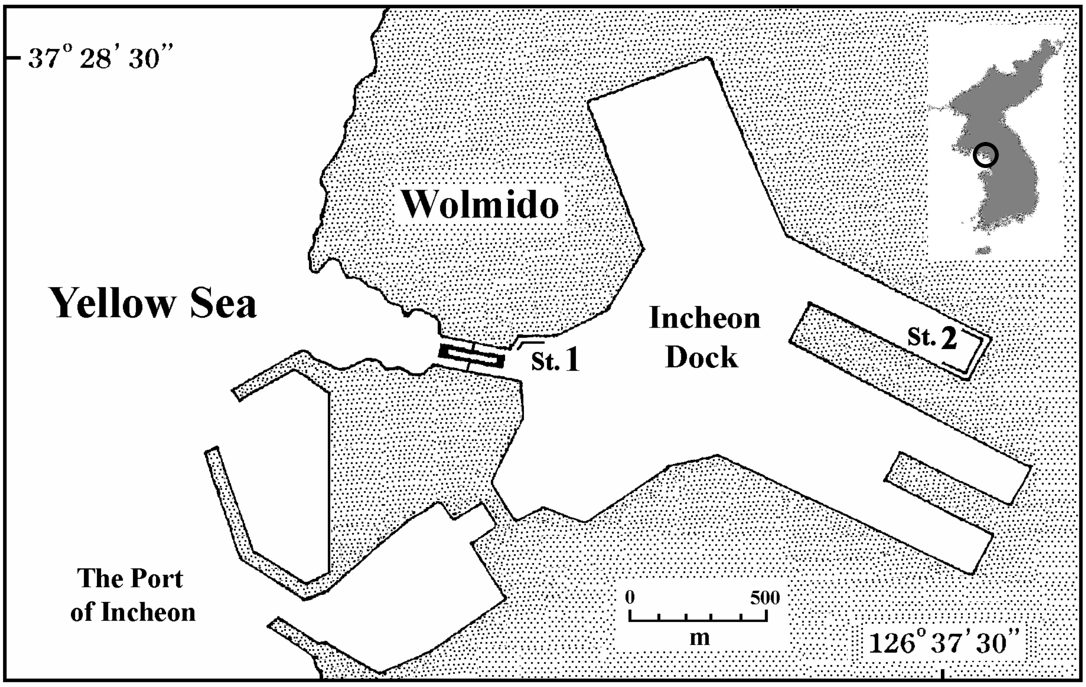

Fig. 1: A map showing the sampling stations in Incheon Dock, western coast of Korea

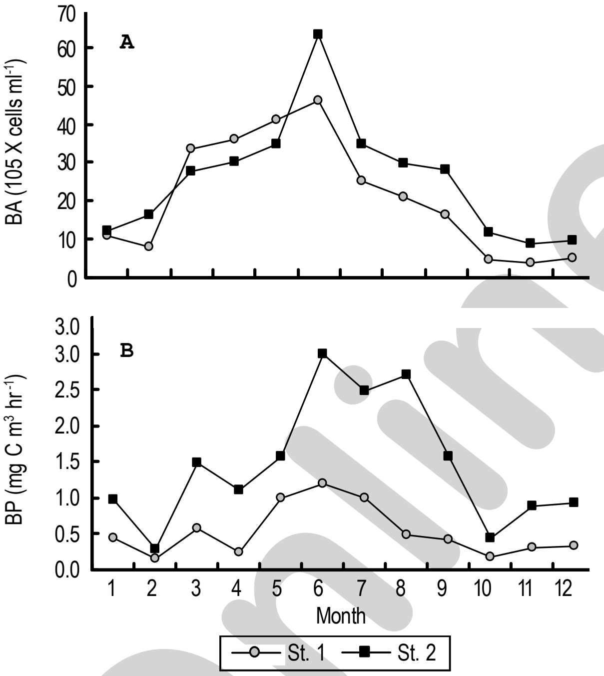

Fig. 2: Monthly fluctuation of bacterial abundance (A) and productivity (B) at the lock gate (LG) and old dock (OD) stations of Incheon Dock in 2002

dock area, representing the old dock area being more stable for bacterial activity, and also being eutrophicated than the lock gate area. The main reason for this seems that the seawater at the old dock does not well circulate due to its topographical condition (Yoo *et al*., 1992; Yoo *et al*., 1997). Besides, the bacterial productivity of Incheon Dock showed high correlations with water temperature and bacterial numbers observed in Gyeounggi Bay, western coast of Korea Choi *et al*. (1997).

Phytoplankton chlorophyll *a* concentrations ranged from 2.1 to 20.1 μg l^{-1} (average: 7.3 μg l^{-1}), high in spring and summer, and low in autumn and winter (Fig. 3A). And the algal blooms by *Skeletonema costatum* occurred in March and August.

The phytoplankton chlorophyll *a* concentrations were lower at Incheon Dock than those at Lake Shiwha which ranged 46.4-318.3 μg l^{-1} (average: 168.0 μg l^{-1}) but they were higher than the values obtained from the other areas in Korea (Chung and Park, 1988; Shin *et al*., 1990; Chung and Yang, 1991; Lee *et al*, 1998; Lee, 2001; Kang *et al*., 2006; Affan *et al*., 2007).

The primary productivity of Incheon Dock was measured between 762.8 and 4,821.6 mg C m^{-2} day^{-1} in spring when the water temperature started rising, however, it was between 58.2 and 139.7 mg C m^{-2} day^{-1} in winter (Fig. 3B). This result seemed to be driven from mixed effects of various factors such as light condition and water temperature, as well as the changes of the assimilation number and the community structure of phytoplankton (Harding *et al.,* 1982; Yoo *et al.,* 1992). The primary productivity was lower at Incheon Dock than that at lake Shihwa which ranged 1,382-9,505 mg C m^{-2} day^{-1} (average: 3,972 mg C) (Choi *et al*., 1997), but definitely higher than those at the other Korean coastal areas. Reported values are as follows: Gyeonggi Bay was 30.3-3,580.0 mg C m^{-2} day^{-1}; Cheonsu Bay, 16.4-767.2 mg C m^{-2} day^{-1}; South Sea, 314.0-1,727.0 mg C m^{-2} day^{-1}; and northern coastal area of Cheju Island, 111.8-1,055.2 mg

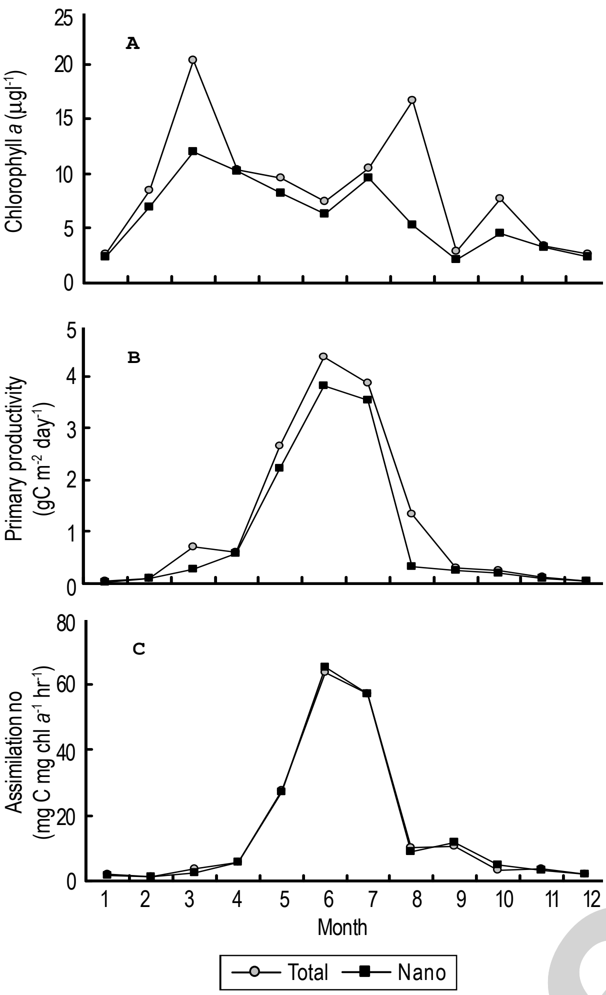

Fig. 3: Monthly fluctuation of chlorophyll *a* (A), primary productivity (B) and assimilation number (C) of total phytoplankton and nanoplankton in the Incheon Dock in 2002. (Total: total phytoplankton, Nano: nanoplankton)

C m^{-2} day^{-1} (Chung and Park, 1988; Shin *et al*., 1990; Chung and Yang, 1991; Lee *et al*., 1998; Lee and Choi, 2000). The daily primary productivity in average was 1,280.2 mg C m^{-2} day^{-1} and the annual primary productivity was 517.0 g C m^{-2} yr^{-1} at Incheon Dock, which was higher not only than those measured at Gyeonggi Bay, Cheonsu Bay and Cheju Island but also than those measured in other costal areas of the world (Chung and Park, 1988). The primary productivity of nanoplankton ranged between 35.3 and 3,807.1 mg C m^{-2} day^{-1}, which accounted for 79.0% of the average daily primary productivity of the total phytoplankton, and the contribution rate over the total chlorophyll-*a* was 81.9%.

The growth of phytoplankton is largely dependent on water temperature, and the level of influence can be estimated by measuring the assimilation number (Li, 1980; Yoo *et al*., 1992). The phytoplankton assimilation number, indicating the maximum photosynthetic efficiency at the light saturation point, was 1.6-67.3 mg C mg chl-a^{-1} h^{-1} (average: 15.9 mg C) and it rose from May to July (Fig. 3C). The assimilation number was higher at Incheon Dock than that at Gyeonggi Bay which had showed the highest assimilation number before (1.2-24.3 mg C mg chl-a^{-1} h^{-1}, average: 7.79 mg C). This indicates that the assimilation number at Incheon Dock is higher not only than that at Gyeonggi Bay but also than those at other areas including even lake Shihwa (2.0-4.5 mg C) and Daecheong Dam (average : 13.1 mg C), which are the two most eutrophicated areas in Korea at the present time (Kang *et al*., 1992; Choi *et al*., 1997).

In conclusion, this study indicates that Incheon Dock has a unique ecosystem, both oceanographically and topographically. It differs from the other areas in terms of abundance and productivity as low trophic level bacteria and phytoplankton are found abundant and highly productive. Phytoplankton assimilation number at that areas is also very high. The uniquely closed environment renders this dock a relatively stagnant water flow, thus, the water being eutrophicated.

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