Marine Nature 2(1), 1989. pp. 111-127

ECOSYSTEM ON THE GULF OF YEONGIL IN THE EAST SEA OF KOREA

5. Dissolved oxygen and rate of oxygen saturation

Ki-Tai Kim, Hong-Joo Yoon, Dong-Cheol Lee

Marine Science Institute, Yeungnam University, 713-749 Gyongsan, Korea

ABSTRACT: From September 1985 to August 1987, the horizontal and vertical variations of dissolved oxygen were studied at the Gulf of Yeongil on the coast of the East Sea of Korea. The concentration of values of dissolved oxygen and rate of oxygen saturation ranged from 6.0 to 8.0ml.l^{-1} and 80 to 120%, respectively. The dissolved oxygen oscillated between 0 and 13.17ml.l^{-1} with an average value of 5.55ml.l-1. The rate of oxygen saturation fluctuated from 0 to 233.8%. The characteristics of the water mass defined by the dissolved oxygen and the rate of saturation varied with the different environments. The annual virations of the these two factors for northern coast area were 6.17ml.l^{-1} and 106.4%, those of central water area 6.18ml.l^{-1} and 104.6%, those of the old port coast area 2.33ml.l^{-1} and 38.1%, those of the POSCO coast area 6.10ml.l^{-1} and 102.8%, and those of the estuary of Hyungsan 6.72ml.l^{-1} and 118.5%, respectively.

Introduction

The Gulf of Yeongil is considered to be the largest water mass area in Korea. This area is environmentally influenced by various oceanographic factors, including both the Rieman Cold and Tsushima Warm Current. The gulf which covers an area of about 115Km has around 2×10^5tons of water. This area is likely to be seriously polluted by many marine evironmental and biological factors (Fig. 1).

The horizontal and vertical variations of dissolved oxygen and rate of oxygen saturation have not been investigated for the Gulf of Yeongil. Partial studies of these factors were reported by Kim (1982, 1983). The biological factors of the coast of East Sea of Korea were investigated by Kwak and Lee (1977), Park (1979), Shim and Pae (1985), and Shim and Lee (1987).

The main purpose of this experiment was to understand the characteristics of the ecosystem and environment by observing the dissolved oxygen and the rate of oxygen saturation which are affected by photosynsis and respiration of plankton, water temperature and the influx of fresh water.

Method and Material

Sea water samples were collected by using the water-sampling bottles (volume; 5 l) made by Hidro-Bios. Co., and collected monthly from September 1985 to August 1987. Readings of the dissolved oxygen was determined by the Winkler method. Rate of oxygen satuaration was calculated by the International Oceanographic Table made by Anony (1973). The water temperature and salinity were directly obtained from the sampling locations in the Gulf of Yeongil in the East Sea of Korea.

Result and Discussion

1. The northern coast area

The northern coast area stretches approximately 10.5 Km from Younghan-dogn (station 1) to the port office (station 3) through Kwandae-dong (station 2).

From September 1985 to August 1987, the average values of dissolved oxygen and rate of oxygen saturation in these areas (mentioned above) were 6.17ml.l^{-1} and

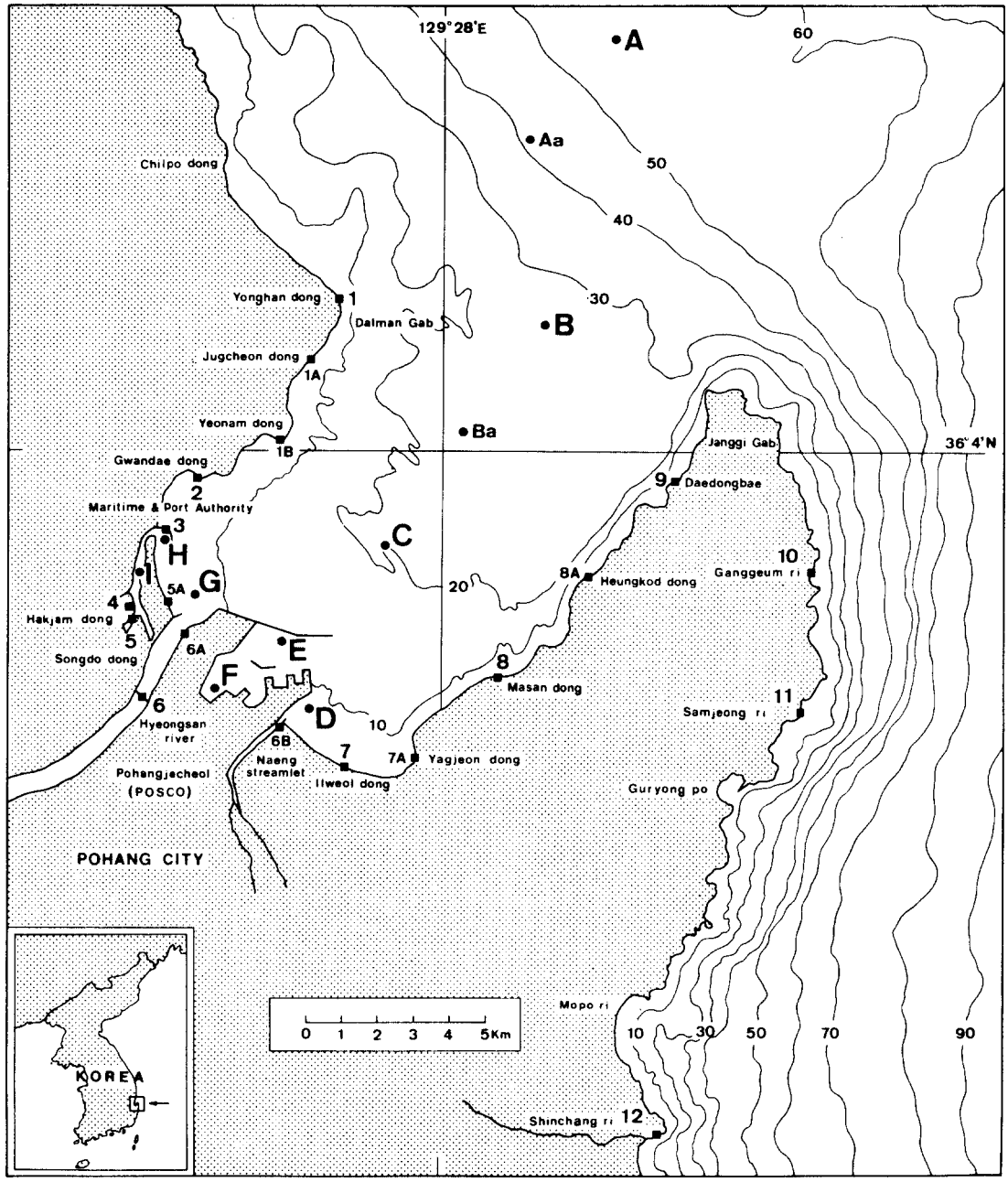

Fig. 1. Location of the sampling station and its area. Gulf of Yeongil in the East Sea of Korea.

106.4% (station 2, April 1987) with maximum values of 9.24ml.l^{-1} (station 2, April 1987) and 165.5% (station 1, May 1987), and with minimum values of 2.77ml.l^{-1} (station 3, September 1986) and 68.3% (station 3, February 1987).

Figs. 4, 5, 8 and 9 show the annual variation of dissolved oxygen and rate of oxygen saturation in this area. Among seasonal variations, the values of dissolved oxygen appeared higher than 7.0ml.l^{-1} in spring (April and May). It would be possible that the phytoplanktons are bloomed by photosynthesis and produce free oxygen in the winter. Otherwise, the values of dissolved oxygen showed lower than 5.5ml.l^{-1} in the winter. This phenomnon was considered to be due to high evaporation and high temperature. The values of dissolved oxygen were extremely low in September and gradually increased in winter. This considered to be due to the gradual increase of temperature and to be affected by the air temperature.

The annual variation of the ranges of dissolved oxygen done in 1987 was compared with that of the range of dissolved oxygen in 1986, and indicated high values. However, the variational patterns of dissolved oxygen and rate of oxygen saturation done in 1987 and 1985 showed similar readings to those done in 1986.

Mean values of dissolved oxygen in this area were relatively low, compared with both the central water area and the southern coast area. Both station 1 which is connected the East Sea of Korea and station 2 which is located on the northern beach showed relatively high values (mean value of dissolved oxygen; 6.71ml.l^{-1}). However, station 3 which is directly effected by the polluted water showed a low value (mean value of dissolved oxygen; 5.09ml.l^{-1}). The rate of oxygen saturation in station 3 also was less than 90%, which indicated polluted water.

2. The southern coast area

The southern coast line from Doku beach (station 7) to Daedongbae-dong (station 9) is about 15.5Km, (Fig. 1). This area is highly affected not only by the several industrial activities of Pohang Iron and Steel Plant (hereafter POSCO) but also by the hydrological changes effected by the local current.

The dissolved oxygen showed a relatively high mean values of 6.66ml.l^{-1} and the rate of oxygen saturation showed over-saturated conditions of 117.7%. Maximum and minimum values showed hgih deviations with a maximum value of 12.6ml.l^{-1} and 233.8% in station 9 (June 1987), and a minimum value of 4.76ml.l^{-1} and 94.6% in station 8 (July 1986).

In seasonal variations, the high values of dissolved oxygen appeared in spring and the low values of dissolved oxygen appeared in summer (Figs. 3, 4). The patterns of variations in the rate of oxygen saturation were similar to that in dissolved oxygen (Figs. 8, 9). The rate of oxygen saturation had a low value in winter, but dissolved oxygen had a low value in summer. It should be speculated that the rate of oxygen saturation showed a low value because dissolved oxygen has a high solubility in the winter.

In annual variation, the mean values of 7.04ml.l^{-1} found during 1985 and 1987 are higher than those of 6.49ml.l^{-1} in 1986. Paticularly, the extreme variations of these values were also seen in the seasonal characteristics of spring readings as taken in June 1987. The values of the rate of oxygen saturation of 1985 and 1987 had high and large deviations compared with those of 1986.

In variations among stations, station 7, which is directly effected by the polluted water of the factorys in the POSCO area, showed extreme low mean values of dissolved oxygen (6.06ml.l^{-1}) and an equally extreme low monthly deviation of values of dissolved oxygen. On the other hand, the mean values of dissolved oxygen showed a high of 6.96ml.l^{-1} and the values of the rate of oxygen saturation appeared beyond 120% as characteristics of the clean water area.

The values of dissolved oxygen were high in the southern coast area as compared with those in the northern coast area. It should be considered that the low values of station 3 resulted from the northern coast area being directly effected by the seriously polluted water in the old port.

3. The central water area

Figs. 2, 3, 6 and 7 showed horizontal and vertical characteristic readings of dissolved oxygen and the rate of oxygen saturation in both station B and 6. Those Figs. indicated the tendency of the diffused processes of pollutants in this area. Oceanographical observations were not taken during the Typhoon in summer (September 1985) or the wind and wave actions in winter (January and July 1986).

The highest values of dissolved oxygen and the rate of

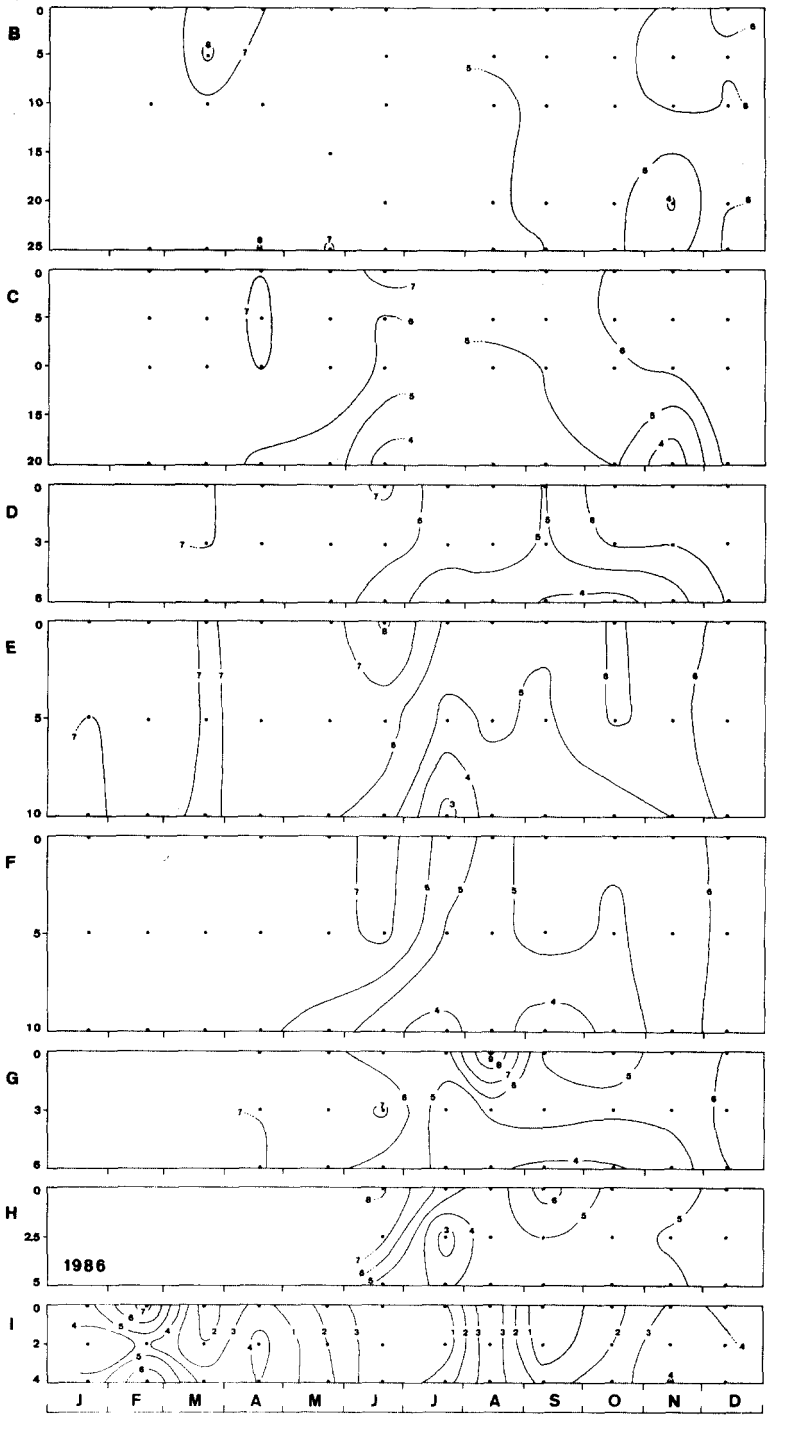

Fig. 2. Annual variation of dissolved oxygen ($ml.l^{-1}$) at stations B-I during 1986

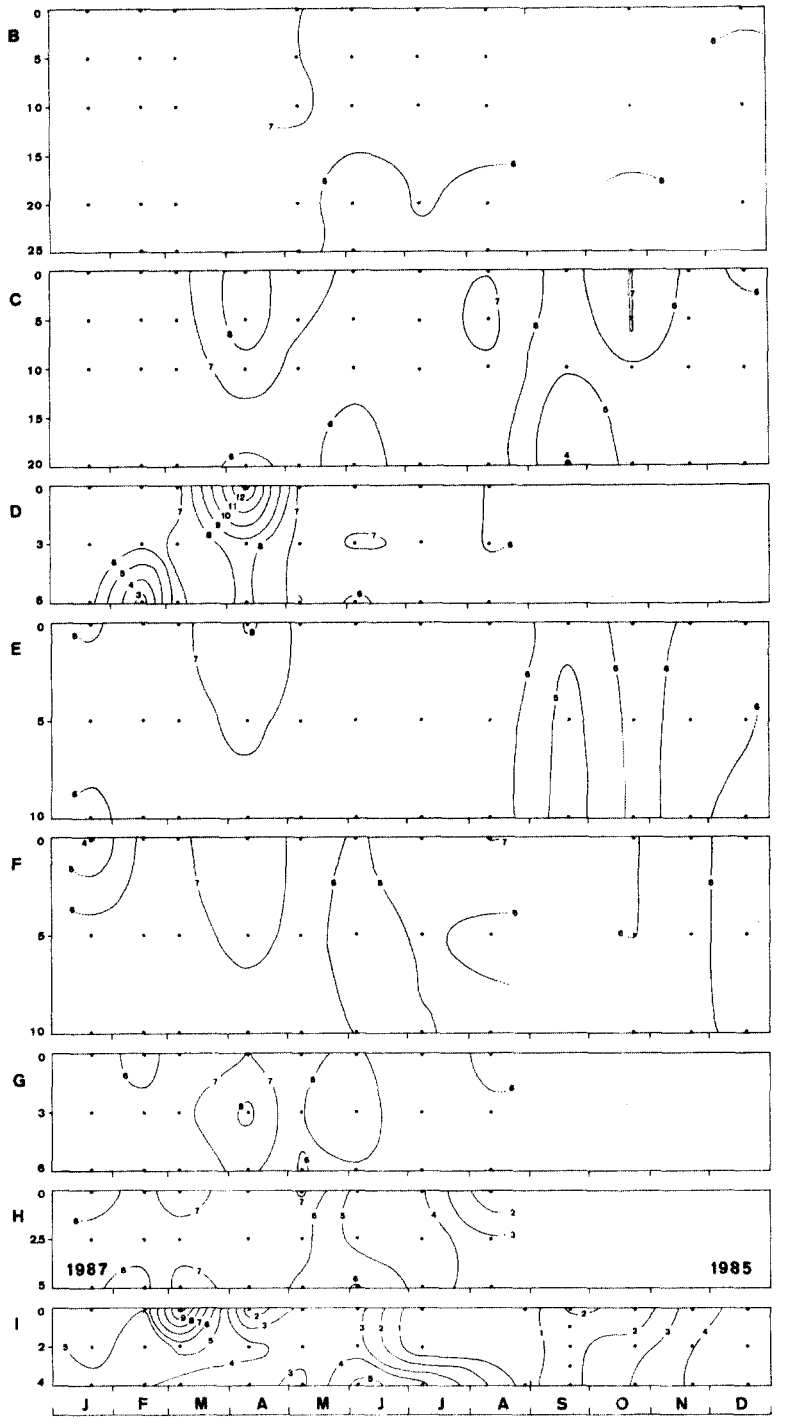

Fig. 3. Annual variation of dissolved oxygen (ml.l^{-1}) at stations B-I from January 1987 to August 1987 and from September 1985 to December 1985.

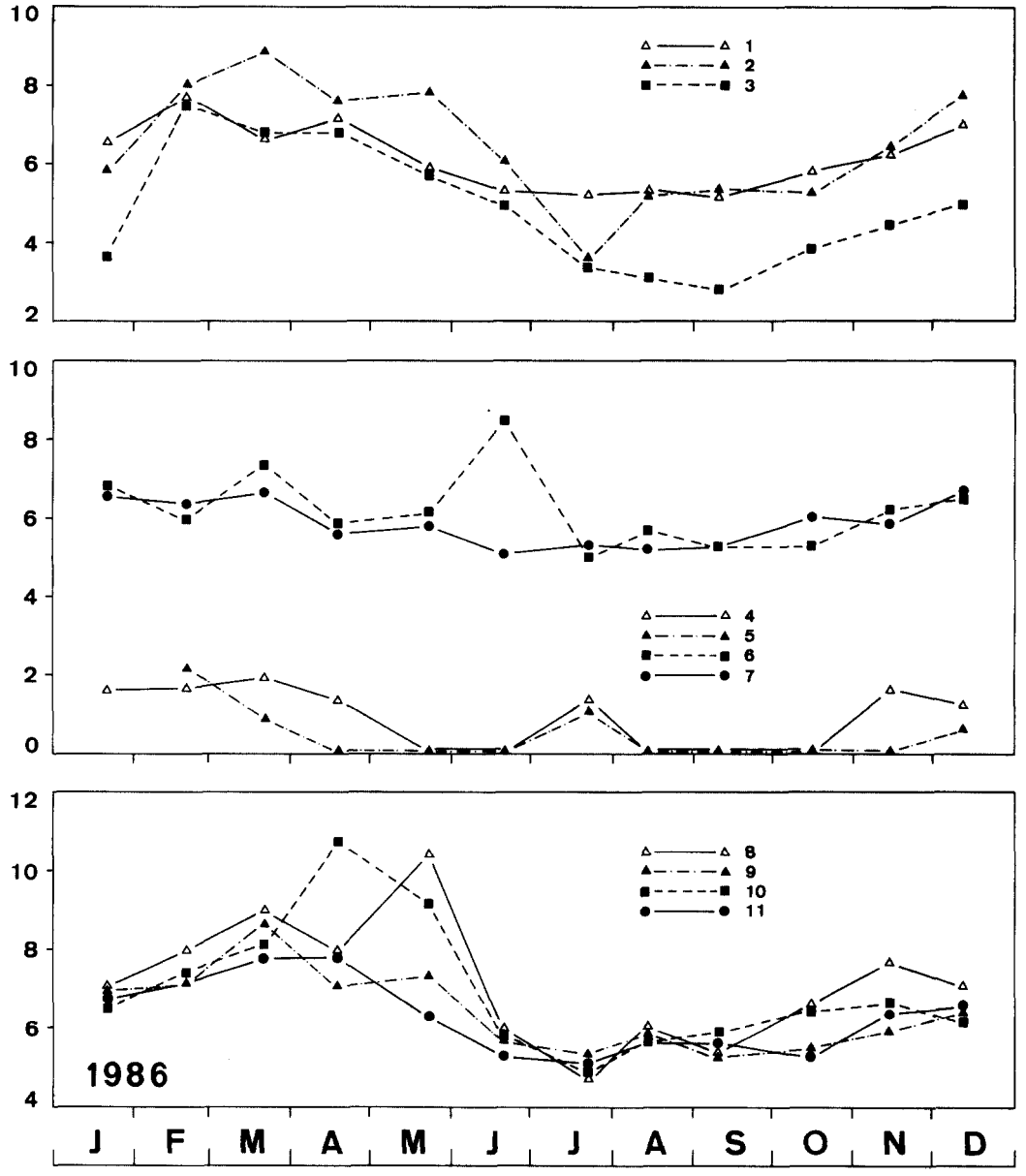

Fig. 4. Annual variation of surface dissolved oxygen ($ml.l^{-1}$) at stations 1-11 during 1986.

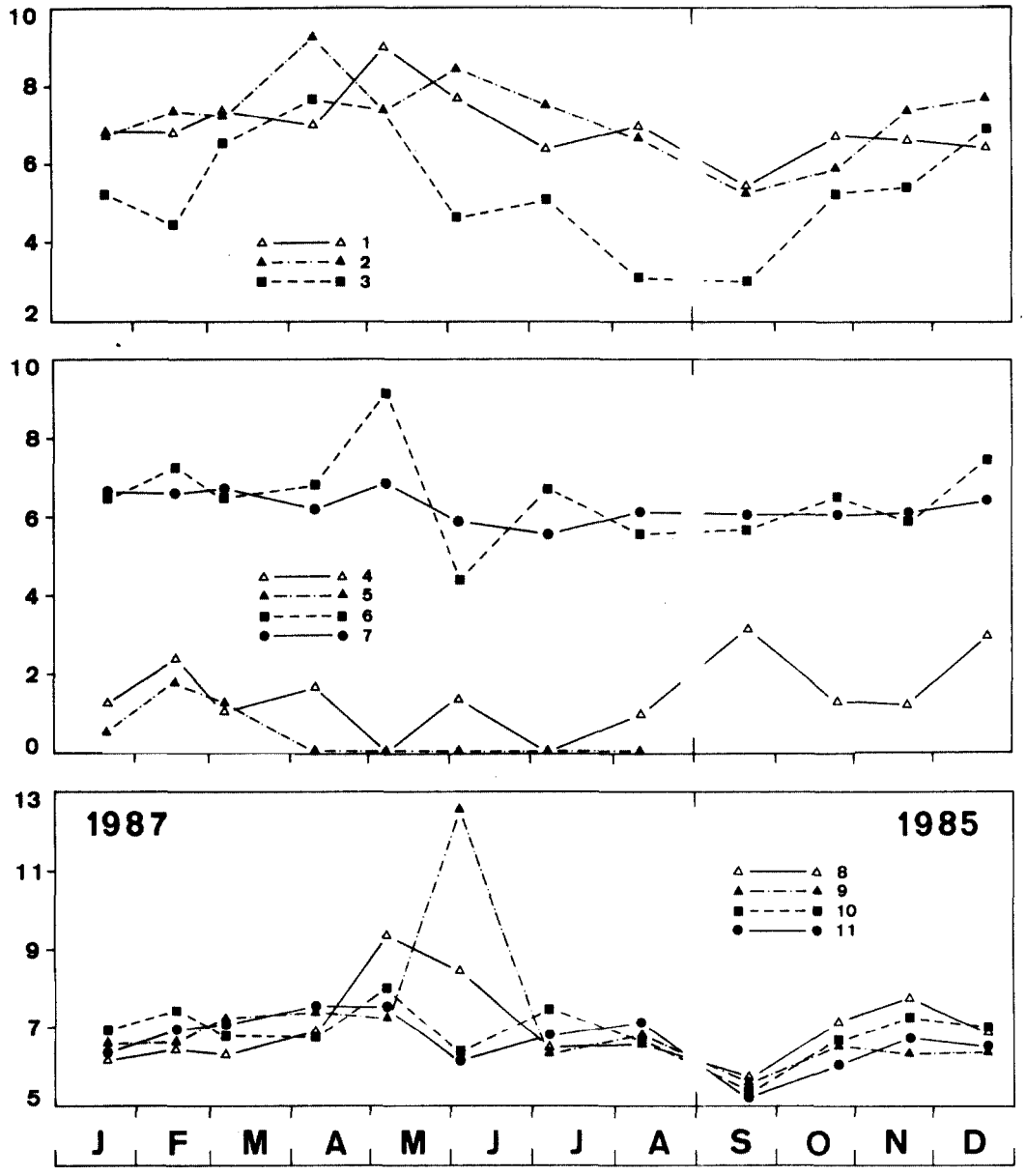

Fig. 5. Annual variation of surface dissolved oxygen ($ml.l^{-1}$) at stations 1-11 from January 1987 to August 1987 and from September 1985 to December 1985.

oxygen saturation in station C were 8.67ml.l^{-1} (5m, April 1986) and 147% (Om, June 1986) ; 3.19ml.l^{-1} (20m, November 1986) and 53.3% (20m, November 1986), respectively. The variation of readings of dissolved oxygen from the average is 5.48ml.l^{-1}. It should be observed that annual variation is large.

In seasonal variations, the values of dissolved oxygen were similar in the upper layer (to 15m below the surface) during all seasons. The dissolved oxygen readings in spring and winter were high, compared with those of summer and autumn. At the low layer (below 15m), the values of dissolved oxygen decreased slowly in June and finally become lowest in November. It should be noted that the dead bodies of phytoplanktons are decomposed by anaerobic bacteria. The phenomena increased abruptly in December and continued at the same rate until the end of May.

The annual variation of values of dissolved oxygen done in 1985 and 1987 showed high readings compared with those done 1986. However, the mean values measured in 1986 of dissolved oxygen had higher values than in 1985 and 1987 at the depth of 25m in station B.

In horizontal and vertical variations, stratifications showed only in station C (June 1985). The deviations between the surface and the bottom layers were low in spring and winter, but they were high in summer.

The values of dissolved oxygen and rate of oxygen saturation in the upper layers appeared high compared to those of the lower layer during all seasons in this area. The mean values of dissolved oxygen and rate of oxygen saturation were 6.18ml.l^{-1} and 104.6%, respectively. It should be considered that the abundant dissolved oxygen resulted from photosynthesis and the exchange of air at the surface layer of sea water in this area.

Generally, the mean values of dissolved oxygen at station B were high compared with those of station C (near POSCO). The difference in readings of dissolved oxygen between the northern coast area and the southern coast area as compared those of the central water area were 0.01ml.l^{-1} and 0.48ml.l^{-1}, respectively.

4. The old port coast area

The old port coast area (small port) is a busy port for small-sized ships. This area was designated as station H and I, and comprises the area from Hakjam-dong (station 4) to Songdo-dong (station 5). This area represented the extreme case of pollution by the sewage from Pohang City and the oil wastes deposited from various kinds of ships.

The mean values of dissolved oxygen in this area were very low, recording 2.33ml.l^{-1} because of the polluted water from factories, the waste oil and the sewage of inhabitants (including the organic waste of the fish). The extreme high and low readings of dissolved oxygen and the rate of oxygen saturation were 10.41ml.l^{-1} (0m, station I) and 156.8% (0m, station H), 0ml.l^{-1} and 0% (all station), respectively.

In seasonal variations (Figs. 2, 3, 4, 5, 6, 7, 8 and 9), the values of dissolved oxygen slowly decreased from spring to autumn and gradually increased from November to February. It is probable that dissolved oxygen in the ecosystem of the hydrosphere was consumed by the proliferatian of phytoplanktons from spring to autumn. The value of dissolved oxygen appeared extremely high from February to March during spring, but extremely low from July to August during summer. It should be speculated that the rates of dissolved oxygen are closly related to water temperature.

In annual variation, mean values of 1987 (dissolved oxygen; 2.72ml.l^{-1}, rate of oxygen saturation ; 42.80%) were high compared to those of 1986 (dissolved oxygen ; 2.00ml.l^{-1}, rate of oxygen saturation ; 33.75%), but the patterns of annual variation of dissolved oxygen were similar, based on two years observations.

During oceanographic observation, station 4 and 5 were almost oxygenless (0-2ml.l^{-1}) from srping to autumn. The value of the rate of oxygen saturation showed ranges from 20% to 60% in all stations.

Comparing the variation between two stations, the mean values of dissolved oxygen and the rate of oxygen saturation at each station were the following; the values of dissolved oxygen and rate of oxygen saturation at stations 4,5,H and I were 1.19ml.l^{-1} and 17.9%, 0.44ml.l^{-1} and 5.9%, 5.27ml.l^{-1} and 90.1%, and 3.13ml.l^{-1} and 51.8%, respectively. Station 5, indicated as a polluted area, shows a marked difference from the others.

The values of dissolved oxygen and rate of oxygen saturation at this area were extremely low compared other areas. These phenomena resulted from the sewage of Pohang City, the shallow depth and the typical characteristics of a colsed water area which is heavily affected by pollutants.

5. The POSCO coast area

This area was constructed for industry and equipped to serve for the steel industry. Thousands of industrial water enter the flow currents. The pollutants at this area are made more toxic or complicated by kinds of polluted materials through various industrial activities. The waste oil deposited from the ships causes serious pollution, and red tides (or black tides) were frequently observed in this area.

Figs. 2, 3, 6 and 7 show the variations of dissolved oxygen and the rate of oxygen saturation at station D, E and F in this area, though station D was observed only after March 1986. Mean values of dissolved oxygen and the rate of oxygen saturation in this area are 6.10ml.l^{-1} and 102.8%, respectively. Values of dissolved oxygen and rate of oxygen saturation in station D are 6.24ml.l^{-1} and 106%, respectively. Values of station E (6.12ml.l^{-1}, 103.4%) are high compared with the mean values of dissolved oxygen and the rate of oxygen saturation in this rea. In the case of station F, mean values of dissolved oxygen and rate of oxygen saturation are a little low compared with other values. This could indicate that value of dissolved oxygen and the rate of oxygen saturation which are affected by cooling waters are gradually increased because of their long distance from this area. High and low values of dissolved oxygen and rate of oxygen saturation in station D are 13.17ml.l^{-1} and 216.6% (0m, April 1987), and 2.55ml.l^{-1} and 29.95 (6m, February 1987), respectively.

In seasonal variations, variations of values of dissolved oxygen appeared small beyond 5m during all seasons, though the values of dissolved oxygen did slightly decreased in summer and autumn. Particually, dissolved oxygen abruptly increased in March 1987 and the waters formed observable stratifications at the end of May in station D. In case of values below 5m, the values of dissolved oxygen decreased extremely in summer and slowly increased in autumn. Deviations of the lower layer inregard to values of dissolved oxygen and the rate of oxygen satuaration are bigger than those of the upper layer in station D. The upper layer appeared over-satuarted, which was thought to result from the photosynthesis by phytoplanktons as the lower layer appeared poorly saturated. In winter, both the upper and lower layers appeared poorly saturated.

In annual variations, the mean values of dissolved oxygen in 1987 (6.40ml.l^{-1}) were superior to those taken in 1986 (5.84ml.l^{-1}). This result comes about because the values of dissolved oxygen in 1987 were low, compared with those of 1986 at the low layer in summer and autumn. Generally, the rate of oxygen saturation values of 1987 was high and attained large variations, compared with those of 1986.

In horizontal and vertical variations, oxycline and stratifications appeared only in station D (April 1987). Variations between the upper and the lower layers in 1986 are remarkably large, compared with those in 1987 which were very small.

Variations among stations were extremely large particularly is station D which is directly affected by fresh waters, and are similar to readings taken in stations E and F.

During oceanographic observations, the POSCO coast area showed the characteristics normally found in polluted water. It should be considered inevitable that this area will gradually be contaminated by the concentration of pollutants.

6. The estuary of the Hyungsan River

This area was checked by stations 6 and G. Station 6 (directly affected by rainfalls) is located in the middle of an old grand bridge in the Hyungsan River. The fresh water and marine water plankton were measured in station G, but remarkably this area did not show any ecosystem of brackish waters.

The mean, high and low values of dissolved oxygen and the rate of oxygen saturation were 6.19ml.l^{-1} and 99.7%, 9.21ml.l^{-1} (August 1986) and 167.2% (August 1986) at the depth of 0m in station G, and 3.79ml.l^{-1} (September 1986) and 70.9% (August 1986) at the depth of 6m in station G, respectively.

In monthly variations, values of dissolved oxygen and the rate of oxygen saturation measured in August 1986 (station G) and May 1987 (station 6) were high, compared with those of June 1987. Generally, the ranges of dissolved oxygen and the rate of oxygen saturation were 6-8ml.l^{-1} and 80-120%, respectively.

Seasonal variations of values of dissolved oxygen appeared small in spring and summer. They did not show any variations in autumn and winter in station 6. The values of dissolved oxygen at station G abruptly decreased from June to September in 1986 and oxycline and stratification phenomena appeared at this time.

Annual variations of values of dissolved oxygen in both years 1985 and 1987 were high, compared with those

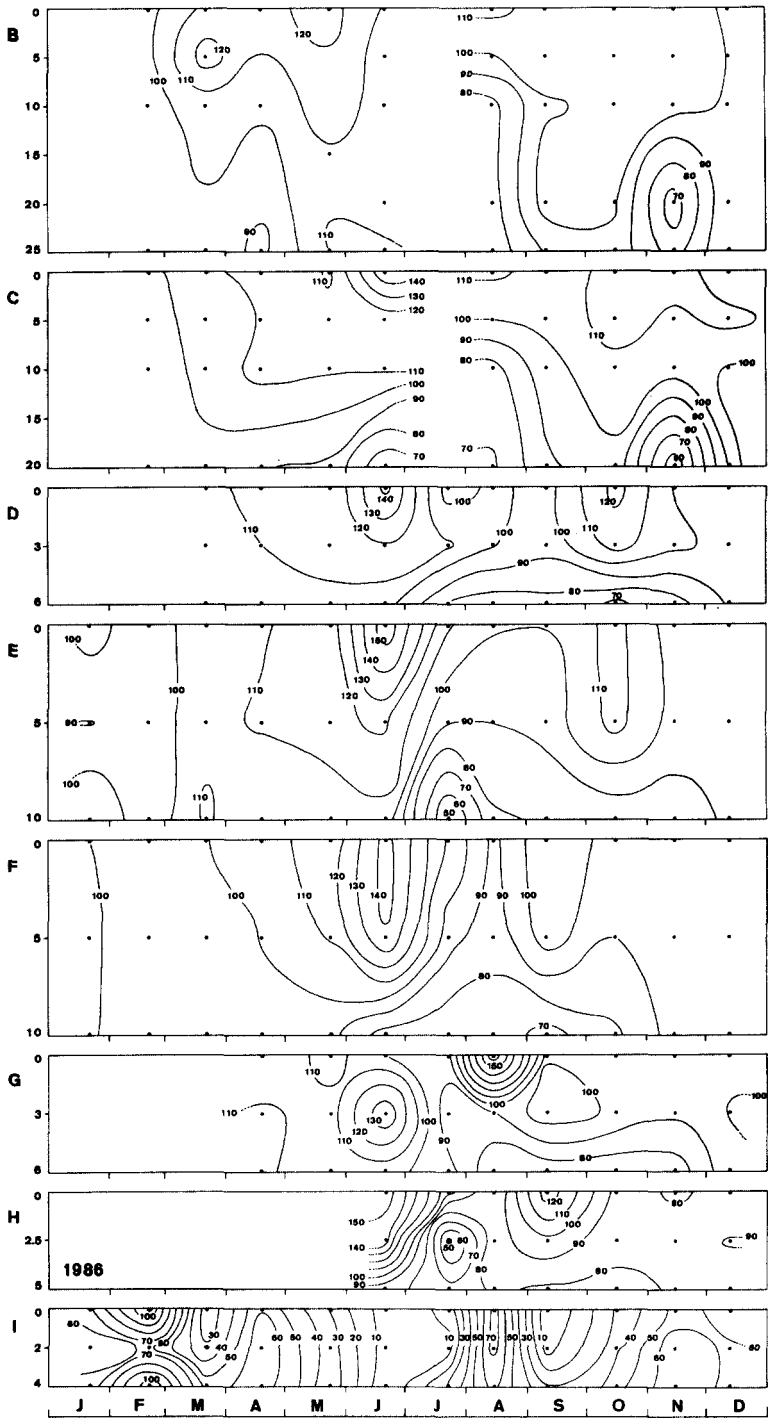

Fig. 6. Annual variation of dissolved oxygen saturation (%) at stations B-I during 1986.

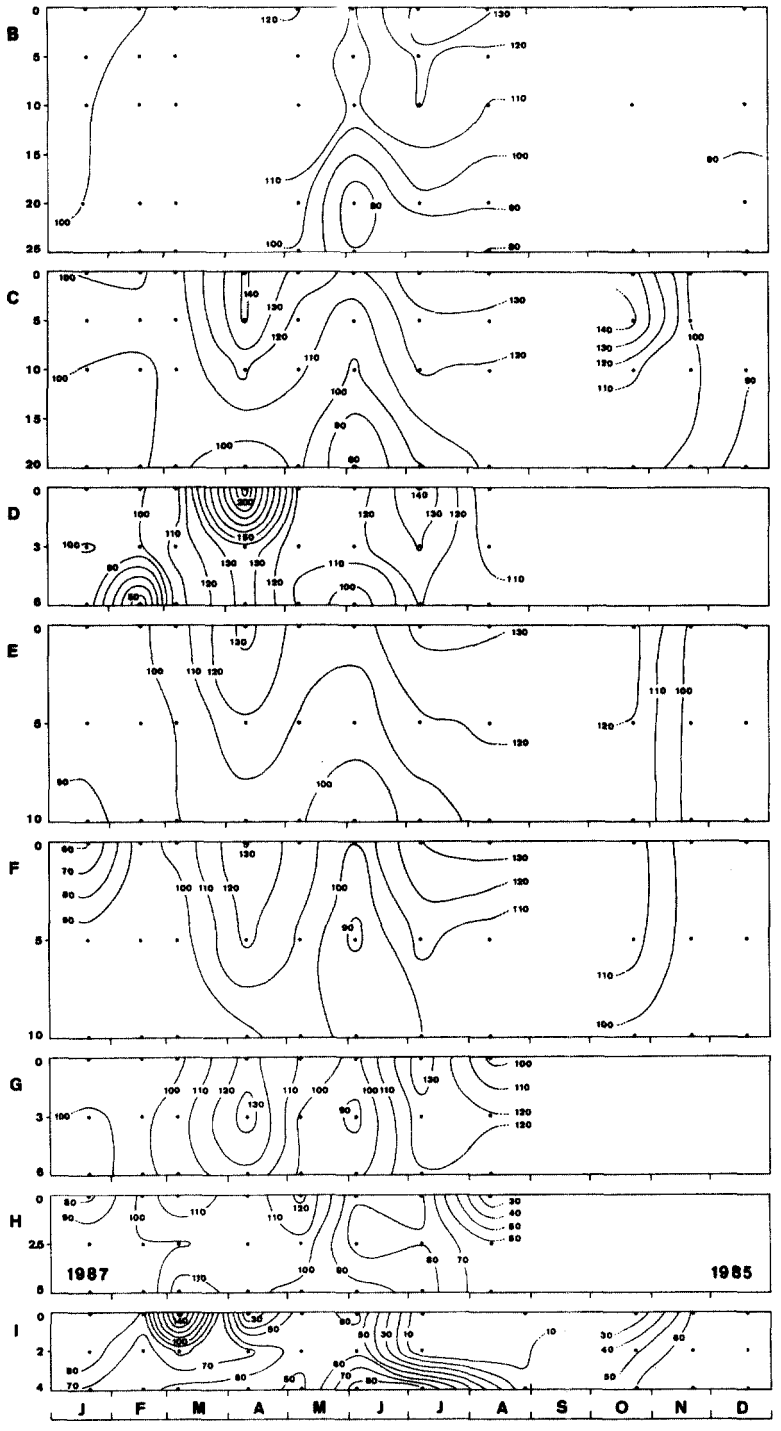

Fig. 7. Annual variation of dissolved oxygen saturation (%) at stations B-I from January 1987 to August 1987 and from September 1985 to December 1985.

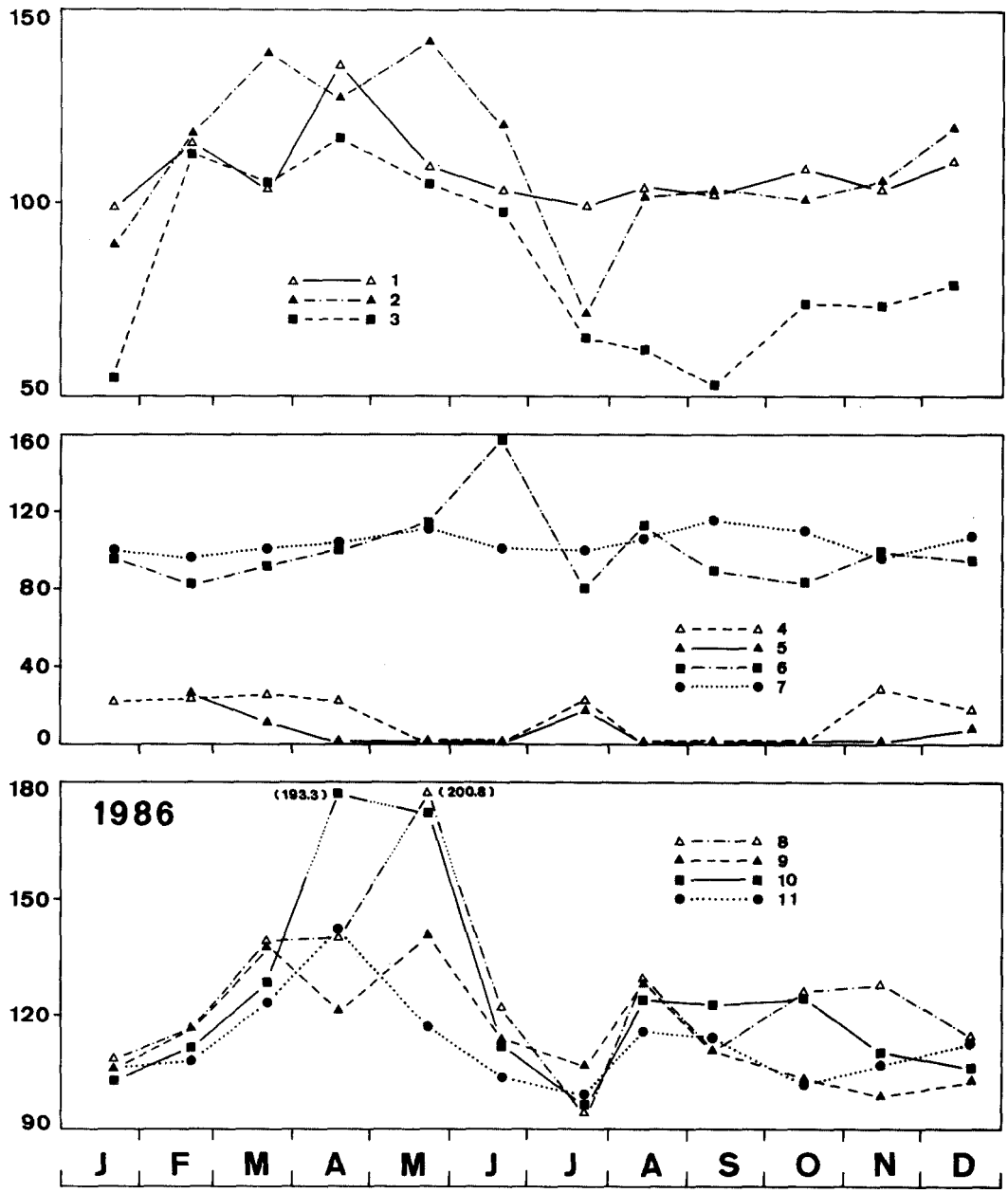

Fig. 8. Annual variation of surface dissolved oxygen saturation (%) at stations 1-11 during 1986.

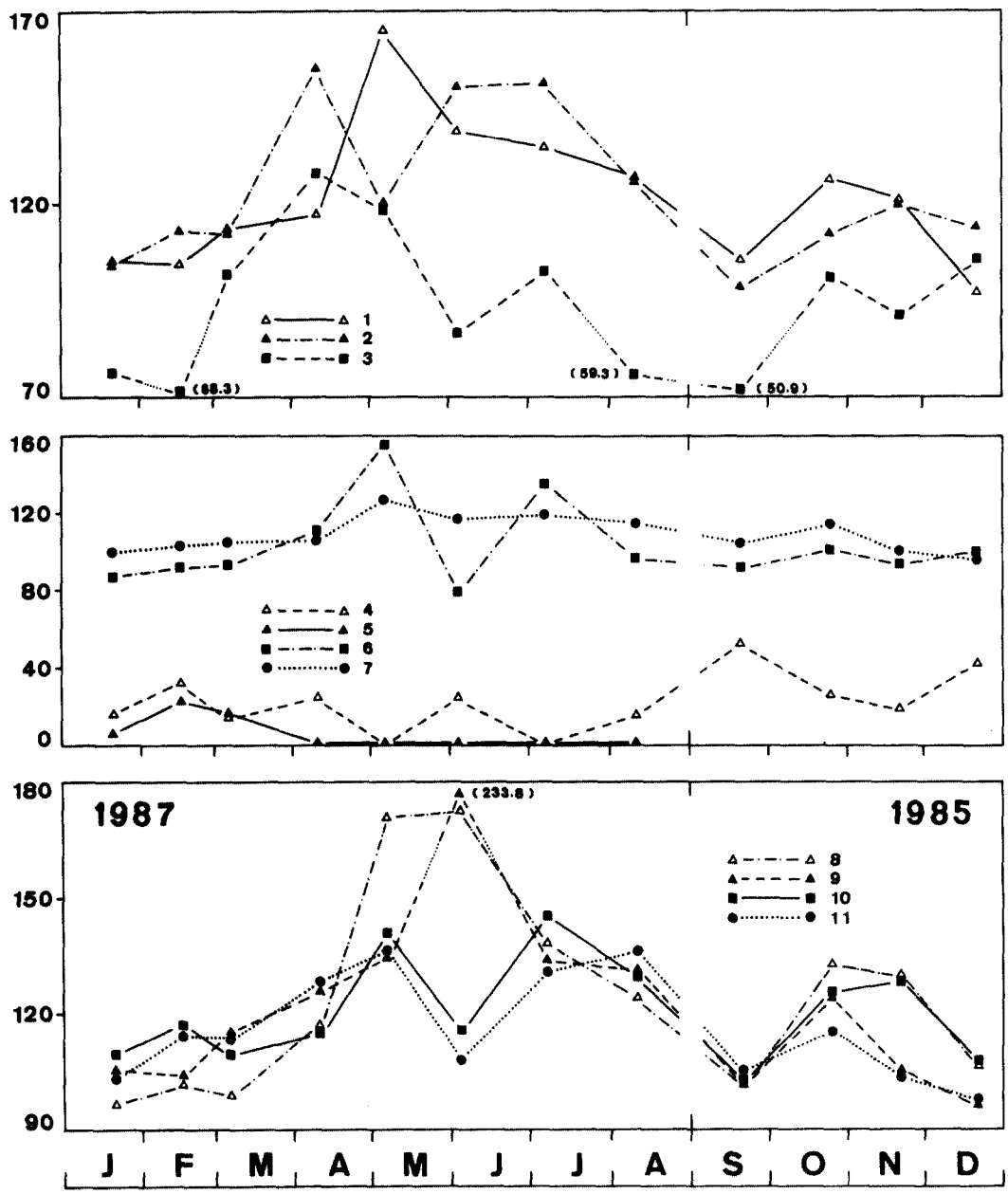

Fig. 9. Annual variation of surface dissolved oxygen saturation (%) at stations 1-11 from January 1987 to August 1987 and from September 1985 to December 1985.

in 1986. Stratification sharply formed at station G in 1986, but stratification did not form at station G in 1987.

The values of dissolved oxygen at station G (directly affected by the industrial polluted waters from POSCO) was 5.93ml.l^{-1} and showed monthly variations as compared with values in station 6 which showed 6.37ml.l^{-1}.

The fresh water of the Hyungsan River was affected by the sewage of the city and agricultural chemicals, it was similar in composition to the polluted water from POSCO and consequently the same extraordinary phenomena which took place in POSCO-influenced areas.

7. The coast area of the East Sea of Korea

The coast area of the East Sea of Korea is located outside the Gulf of Yeongil which is directly affected by the polluted water. However, the water in this coastal area was clean. These areas are called Ganggeum-ri (station 10) and Gurong-po (station 11). This area was a standard example area, to study and compare the ecosystem of the Gulf of Yeongil and the East Sea.

Mean, high and low values of dissolved oxygen and the rate of oxygen saturation were 6.72ml.l^{-1} and 118.5%, 10.73ml.l^{-1} and 193.3% in April, and 4.88ml.l^{-1} and 96.3% in July at station 10 in 1986.

Seasonal variations of dissolved oxygen and rates of oxygen saturation appeared high in spring (Figs. 4, 5 and Figs. 8, 9) in April and May, and appeared low in summer. Also, they slowly increased after autumn. The values of rate oxygen saturation appeared low in winter.

The annual variations of dissolved oxygen in the spring of 1986 and summer 1987 appeared high, and variations in 1987 were large compared with those in 1986 (Figs. 4, 5, 8 and 9). The variations of dissolved oxygen generally were almost similar each other.

The variations of values of dissolved oxygen and the rate of oxygen saturation at station 10 and 11 (which are affected by the cold current in the East Sea of Korea) were 6.94ml.l^{-1} and 122.7%, and 6.44ml.l^{-1} and 114.5% (Kim, 1983), respectively.

The variation of values of dissolved oxygen at the coast area of the East Sea of Korea appeared high compared to other areas. Also, the rate of oxygen saturation appeared over-saturated (beyond 100%) in all periods except in July and December.

Conclusion

Dissolved oxygen and the rate of oxygen saturation in the Gulf of Yeongil were absolutely affected by the variations of water temperature. The values of dissolved oxygen were low in summer and high in winter (Fig. 10).

Relations between water temperature and values of dissolved oxygen were investigated from September 1985 to August 1987 in order to ascertain the representative characteristics of the Gulf of Yeongil.

The rate of oxygen saturation was calculated by employing International Oceangraphic Tables (Anony, 1973) which showed a mean salinity of 35.5% in this area. Usually, the values of dissolved oxygen had a range of 50-150%, but according to our measurements, the values of dissolved oxygen showed a range of 90-120%. It should be noted that the water in this area is clean. Therefore, the water is believed to be contaminated if it shows a range of 90% or under.

Station C at displayed values of depths between Om and 5m in this area which is a clean water area, dissolved oxygen and the rate of oxygen saturation at 7ml.l^{-1} and beyond 140%, respectively. However, the values of dissolved oxygen and the rate of oxygen saturation at the depth of 20m in this area were quite low. The values of dissolved oxygen and the rate of oxygen saturation were about 3ml.l^{-1} and 50%, respectively. The results indicate that the low layer water in this area presents a quite small quantity of dissolved oxygen. Consequently, dissolved oxygen in the water is realily exhausted by the pollutants.

The values of dissolved oxygen were relatively high (6-7ml.l^{-1}) in winter (from December to March) and spring (from April to May) compared with low values (5-6ml.l^{-1}) in summer (from June to September). It should be kept in mind that the values of dissolved oxygen are reduced by the influence of the Kuroshio Warm Current (Kim, 1983).

The relations between water temperature and dissolved oxygen were remarkably similar in stations B and C (Fig. 10). Fig. 11 indicates the mean values of dissolved oxygen and the rate of oxygen of 1985, 1986 and 1987 at the depth of 0m in all station in the Gulf of Yeongil.

Stations 1 and 2 belonging to the northern coast area have high values of dissolved oxygen compared with other station in the Gulf of Yeongil. It should be noted that this area has characteristics of a relatively clean water area. Station 3 (affected by the old port) had a large quantity

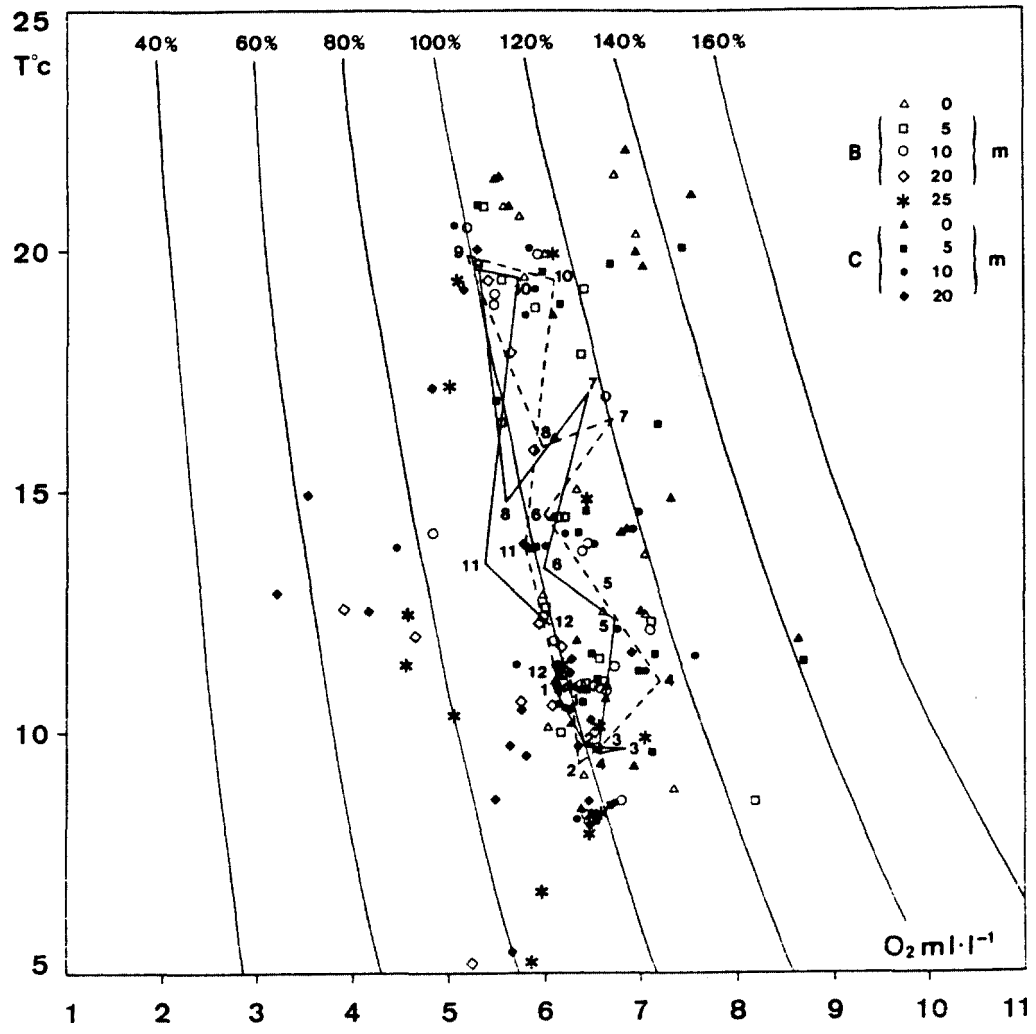

Fig. 10. Relations between water temperature and dissolved oxygen at stations B and C. The graphs join average values for each month (shown by a number): continuous line: station B; broken line: station C.

of pollutants.

Both the central water area (stations B and C) and the southern coast area (stations 7, 8 and 9) have high values of dissolved oxygen and rates of oxygen saturation. One may say that these areas have the characteristics of normal sea water.

The values of dissolved oxygen were taken in both POSCO and coast stations (stations D, E and F) and in the estuary of the Hyungsan River (stations 6 and G). It should be noted that this area is affected by the industrial pollution connected with the iron manufacturing industry and added to by the sewage system (Pohang City).

The old port which is directly affected by the water polluted by Pohang City outflows is a very seriously contaminated water area. From time to time, dissolved oxygen is at almost a "zero" condition and generally, dissolved oxygen is never at a regular or normal value. Therefore, it should be urgently hoped the magagement pollution control for the sewage of the inhabitants of Pohang City.

Fig. 11 shows the processes of diffusion of various pollu-

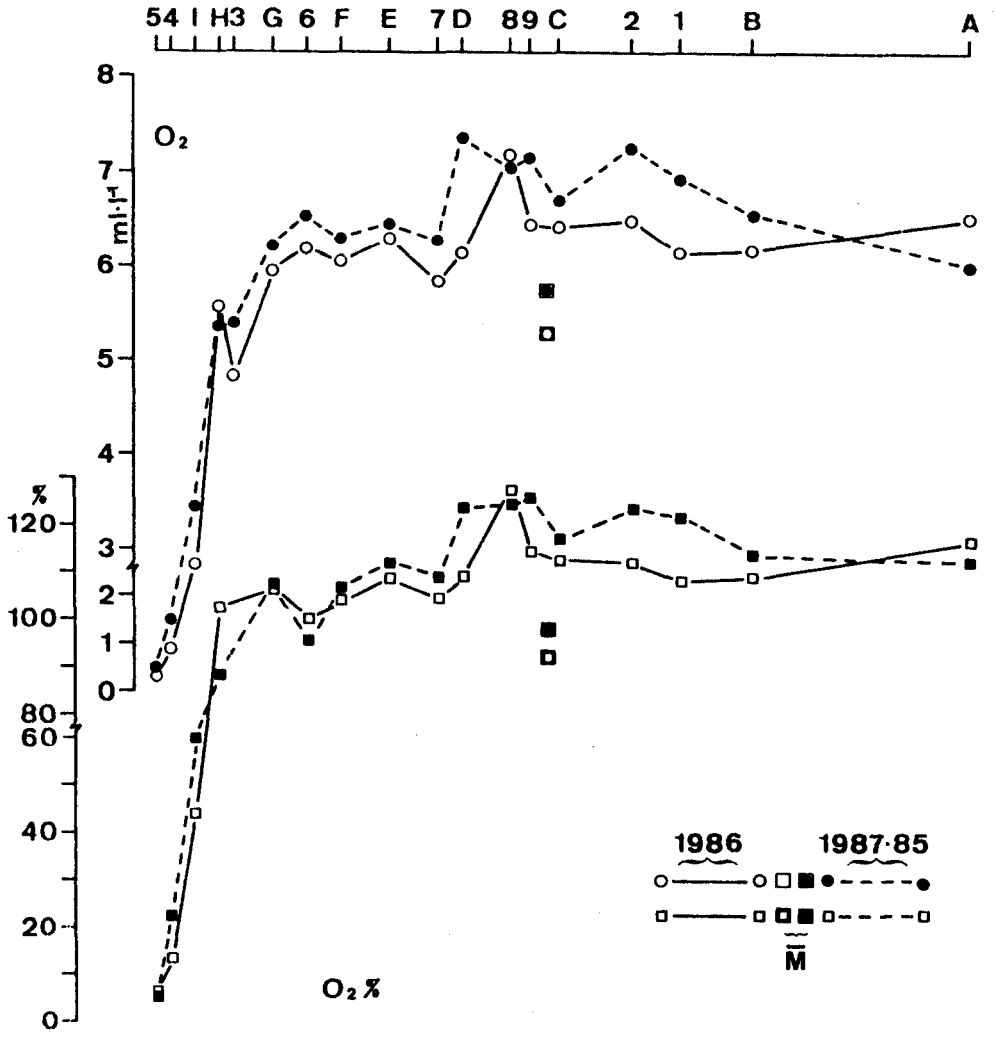

Fig. 11. Dissolved oxygen concentration and saturation rate at most station in 1986 and 1987, 1985 (surface annual average).

tants from the old port coast area to the East Sea of Korea in time and in space. The old port coast area is in a serious contaminated condition according to the values of dissolved oxygen which almost always appeared low. However, the more the oceanographic observation stations went outward into the East Sea of Korea, the more the values of dissolved oxygen became high.

The values of dissolved oxygen has inversely relation with water temperature and decreases as the result of indigent oxygen which oxidized by the organisms and the pollutants in the Gulf of Yeongil. The values of dissolved oxygen appeared conditions of increase or decrease by the photosynthesis and respiratory rate of phytoplanktons. Moreover, the values of dissolved oxygen has a plenty of quantity of oxygen in accordance with gas is vigourly exhanged from the air to the surface layer by the wind. Generally, the values of dissolved oxygen extremely appeared poor oxygen in the bottom layer in the Gulf of Yeongil, it should be speculated that the values of dissolved oxygen is topographically affected by the depth.