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

4. Horizontal and vertical distribution of salinity and density

Ki-Tai Kim, Ki-Bong Lim,[1] Kwang-Ho Paik,[2] Hong-Joo Yoon

Marine Science Institute, Yeungnam University, 713-749 Gyongsan, Korea
1) Oceanographic Section, Fisheries Research & Development Agency, Pohang, Korea
2) Department of Geology, Korea University, 136-701 Seoul, Korea

ABSTRACT: The oceanographic characteristics of the Gulf of Yeongil were studied by using salinity and density readings obtained "in situ" from September 1985 to August 1987. The characteristics of salinity and density are directly affected by fresh waters induced from precipitation in summer and evaporation induced from latent heat loss in winter. Seasonal and annual variations of all horizontal stations are very similar to one another. Vertical variations of stations located in order to observe the vertical characteristics appear sharply to have an effect on the stratification patterns, such as halocline and pycnocline in summer and the homogeneous patterns in winter. Interesting variations are found out the stratification patterns at the surface layer in July and the upwelling phenomena at the bottom layer in August. It indicates that the former is the result of an inflow of fresh water from the Hyungsan River and the latter is the result of an intrusion of cold water from the East Sea.

Introduction

The Gulf of Yeongil which is directly connected to the East Sea is approximately 115Km^2 with a volume of 2×10^5 tons. This area is naturally influenced by the oceanographic environmental characteristics of both cold and warm current of the East Sea, artificially by the waste waters induced from Pohang City and mammoth iron industry, by the fresh waters of the Hyungsan River, by topography and climate, and many other factors.

Particularly, water masses of the lower layer have a definite influence on salinity and density, and both cold and warm currents contribute variously to the variational range of salinity and density.

Variations of salinity are influenced by the inflow of fresh water, evaporation, precipitation, and the freezing or melting of sea water (Dietrich et al, 1980).

Salinty has a large influence on the control of osmostic pressure, the fertilization and development of spawn in fishes (Taivo, 1981), and the growth, breeding, fluctuation and other factors effecting in phytoplanktons (Kim et al, 1987).

The main purpose of this research which basically studies the ecosystem of the Gulf of Yeongil are for reporting the characteristics of the environment, the possibilities of development of fisheries, the study of fisheries, and the index of primary production of phytoplankton in the Gulf and the East Sea of Korea.

Method and Material

Sea water samples were collected by using the water-sampling bottles (Volume; 5l) made by Hydro-Bios. Co. and collected monthly from September 1985 to August 1987. Readings of salinity was determined by using the Induction Salinometer 601 MK-N made by MFG Co. (standard sea water; K_{15} = 0.99997, chlorinity = 19.3745). Density was calculated by the Sigma-t Table made by Keala.

Result and Discussion

1. The northern coast area

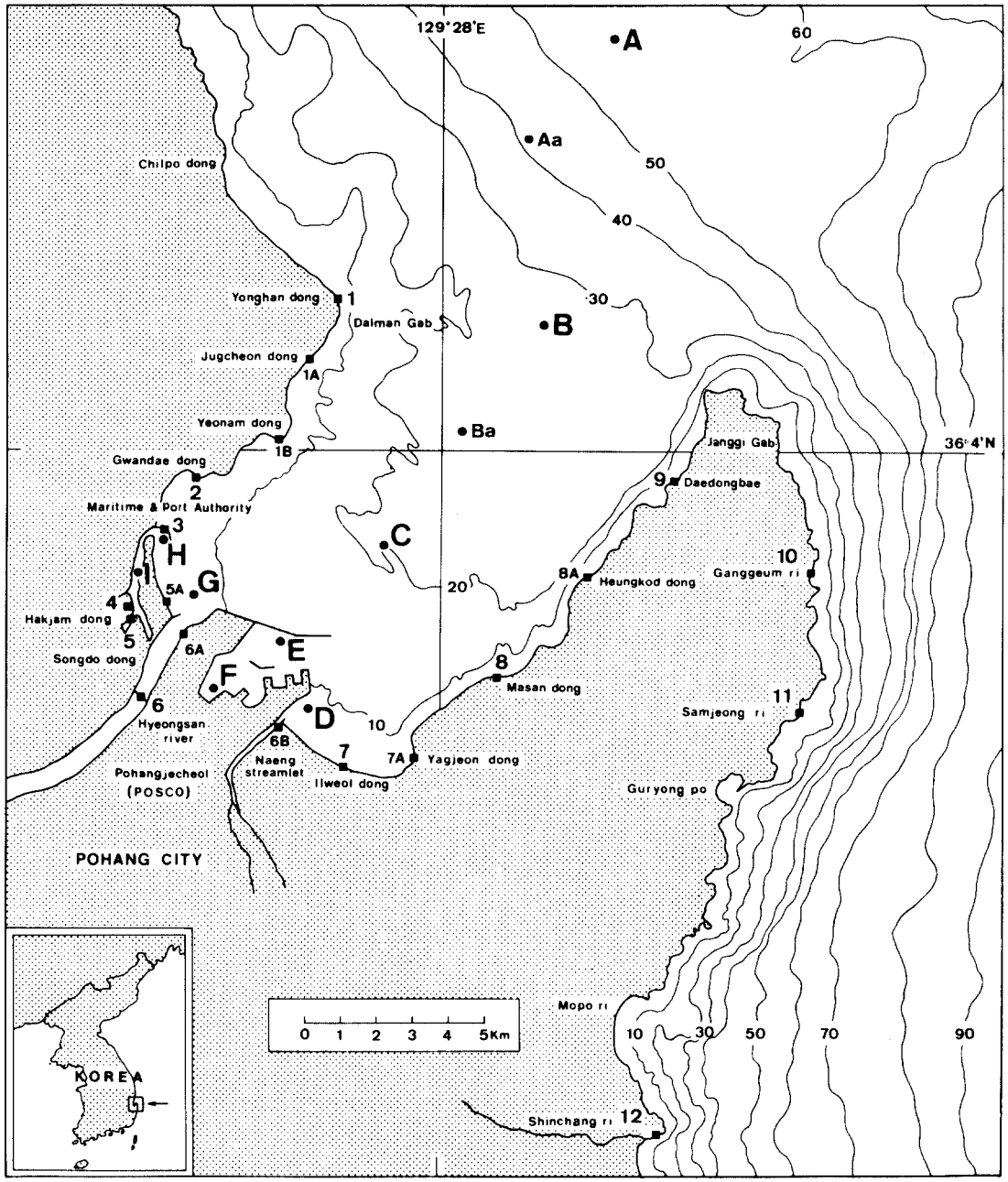

Fig. 1. Location of the sampling station and its area. Gulf of Yeongil in the East Sea of Korea.

The northern coast line is approximately 6.3 Km from Yonghan-dong (station 1) to Gwandae-dong (station 2), (Fig. 1). Yonghan-dong which is adjacent to the uncontaminated waters of the East Sea of Korea is a less polluted are compared with Gwandae-dong, but Gwandae-dong is badly contaminated and the degree of pollution is intense because of sewage (port contamination, sewage of inhabitants, excrement).

The annual average, maximum, and minimum of salinity and density are 32.97‰ and 24.20;34.84‰ (station 1, August 1986) and 24.20 (station 2, February 1986) ; and 21.41‰ (station 2, September 1985) and 13.76 (station 2, September 1985) in the northern coast area, respectively.

(1) Seasonal variation

Figs. 4, 5 show the extreme average value of 43.10‰ in winter (December, January, February and March) and the similar values from spring (April) to early summer (June). The values become the largest in winter. The values fall abruptly in July and rise suddenly in August, though the values fall relatively and rise slowly in September.

High salinity is caused by the evaporation of sea water and the inflow of small amounts of fresh water. The various phenomena of evaporation are caused by latent heat loss (Kang, 1983). Kang said that sea water evaporated even when the temperature was low, and that salinity increases when heat radiates from warm sea water to the cool air during dry and cool weather in winter. Chang (1976) said that the effects of evaporation of sea water which was caused by latent heat loss could not be neglected in winter.

Salinity falls abruptly in July. This indicates that much fresh water flowed into the Gulf from the concentrated heavy rain,but Gwandae-dong which is located nearly at the mouth of the Hyungsan River has high salinity compared with Yonghan-dong. It should be noted that the circulation of currents is slowed by topographical effects. Because of this, Yonghan-dong is estimated to have a degree of pollution that will be heavy in the future.

Salinity has high values in August because sea water is evaporated by radiant heat in summer. Salinity falls abruptly in September. This is caused by the evaporation decrease as the atmosphere temperature drops, and relatively fresh water becomes larger in quantity than the loss from evaporation.

Figs. 8, 9 show variations of density. This appears in similar readings along with salinity and one notes high density in February as compared with high salinity in August. It should be explained that density increases in winter because the surface sea water is colded by the northwestly monsoon wind (the effect of advection) and the cool air (the effect of cooling).

(2) Annual variation

Salinity in 1986 had a low value of 14.24‰ in September and relatively high values in October and November compared with these of 1986. On the whole, salinity of 1986 and 1987 have similar readings. However salinity in 1987 shows a high value of 5.14‰ compared with those of 1986 in July. This was caused by relatively little fresh water flowing into the Gulf from rainfall in July 1987.

(3) Variation among stations

The 32.80‰ (average value) of Gwandae-dong (station 2) shows a low value of 0.25‰ and a deviation of 13.23‰ compared with Yonghan-dong (station 1). It should be considered that Gwandae-dong which is adjacent to the Hyungsan River and Pohang City was directly effected by the inflow of fresh water and waste water as compared with Younghan-dong which is located by an uncontaminated area of the East Sea of Korea.

2. The southern coast area

The southern coast area is approximately 15.5 Km from Doku Beach (station 7) through Masan-dong (station 8) to Daedongbae-dong (station 9), (Fig. 1). Especially, Doku Beach which is a sandy seashore connected to POSCO (Pohang Iron and Steel Plant) and the Naeng streamlet are heavily affected by industry waste water and fresh water. The southern coast area is more severely polluted than the northern coast area.

The annual average, maximum, and minimum of salinity and density are 32.19‰ and 23.38 ; 34.46‰ (station 9, March 1983) and 26.82 (station 9, February 1986) ; 11.09‰ (station 7, September 1985) and 6.36 (station 7, September 1985) in southern coast area, respectively.

(1) Seasonal variation

Salinity has a high value of 33.83‰ in winter and gradually falls in spring (March) compared with the northern coast area. Salinity falls to 30.09‰ in summer and rises slowly in a regular progression from September to February.

Salinity falls slowly in spring compared with the northern coast area. It should be considered that the Tsuchima Current which proceeds northward flowing past the coast

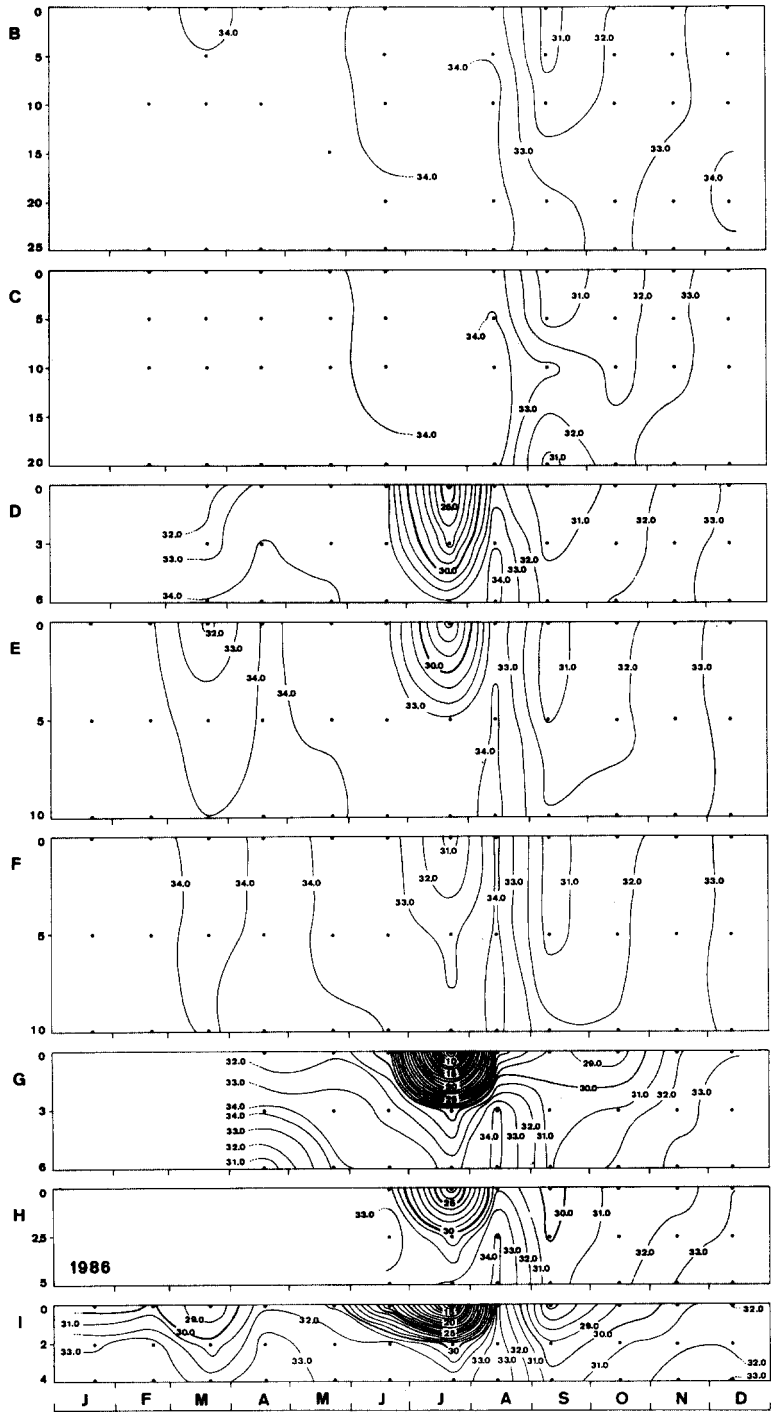

Fig. 2. Annual variation of salinity (S‰) at stations B-I during 1986.

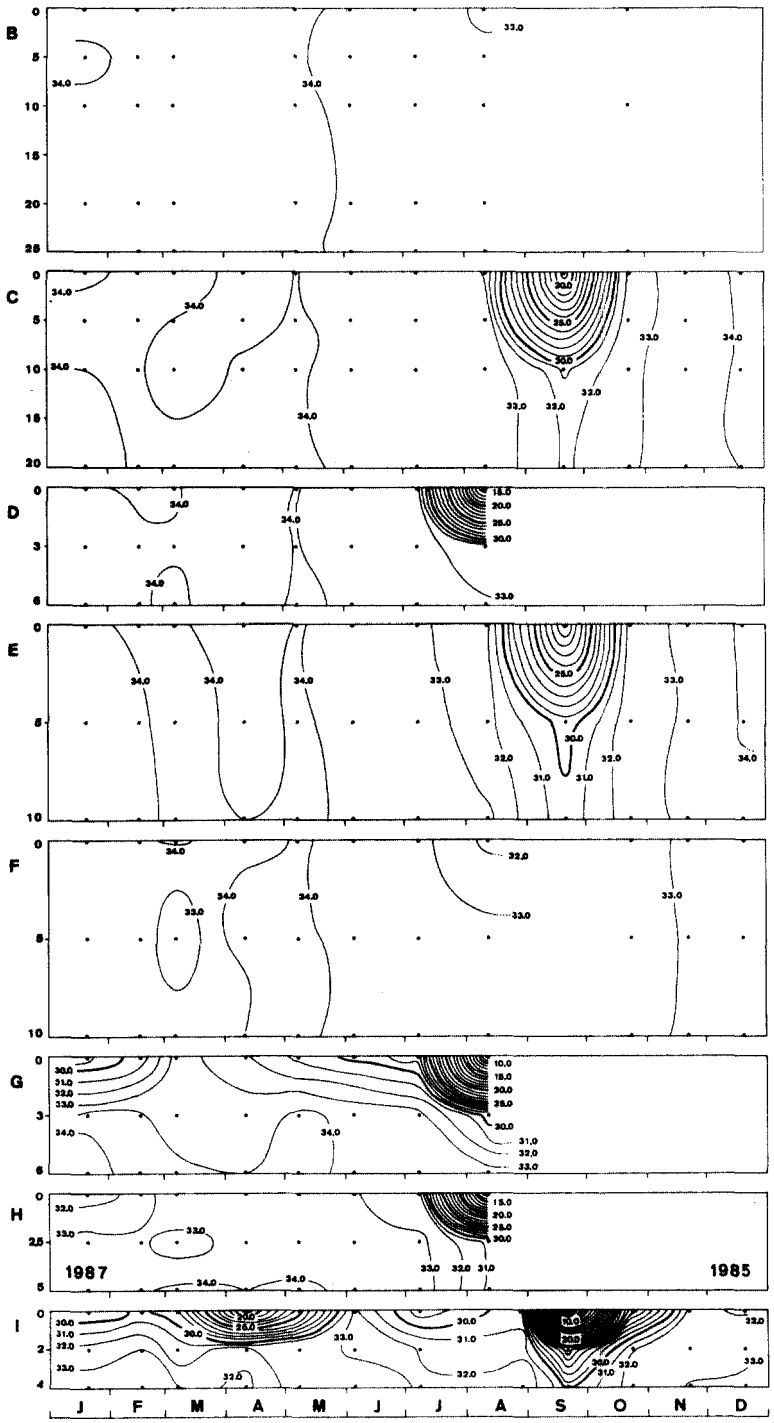

Fig. 3. Annual variation of salinity (S‰) at stations B-I from January 1987 to August 1987 and from September 1985 to December 1985.

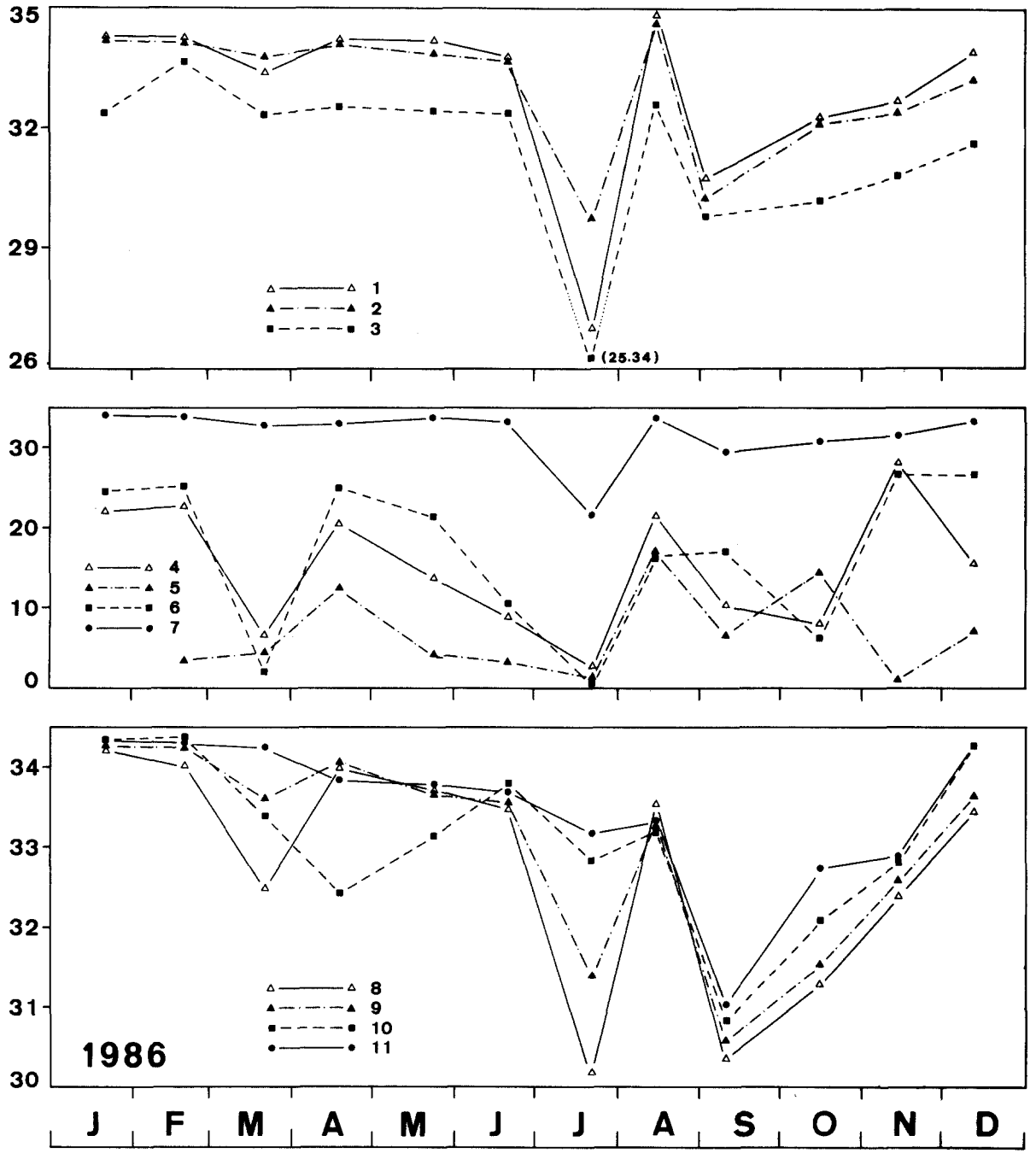

Fig. 4. Annual variationof surface salinity (S‰) at stations 1-11 during 1986.

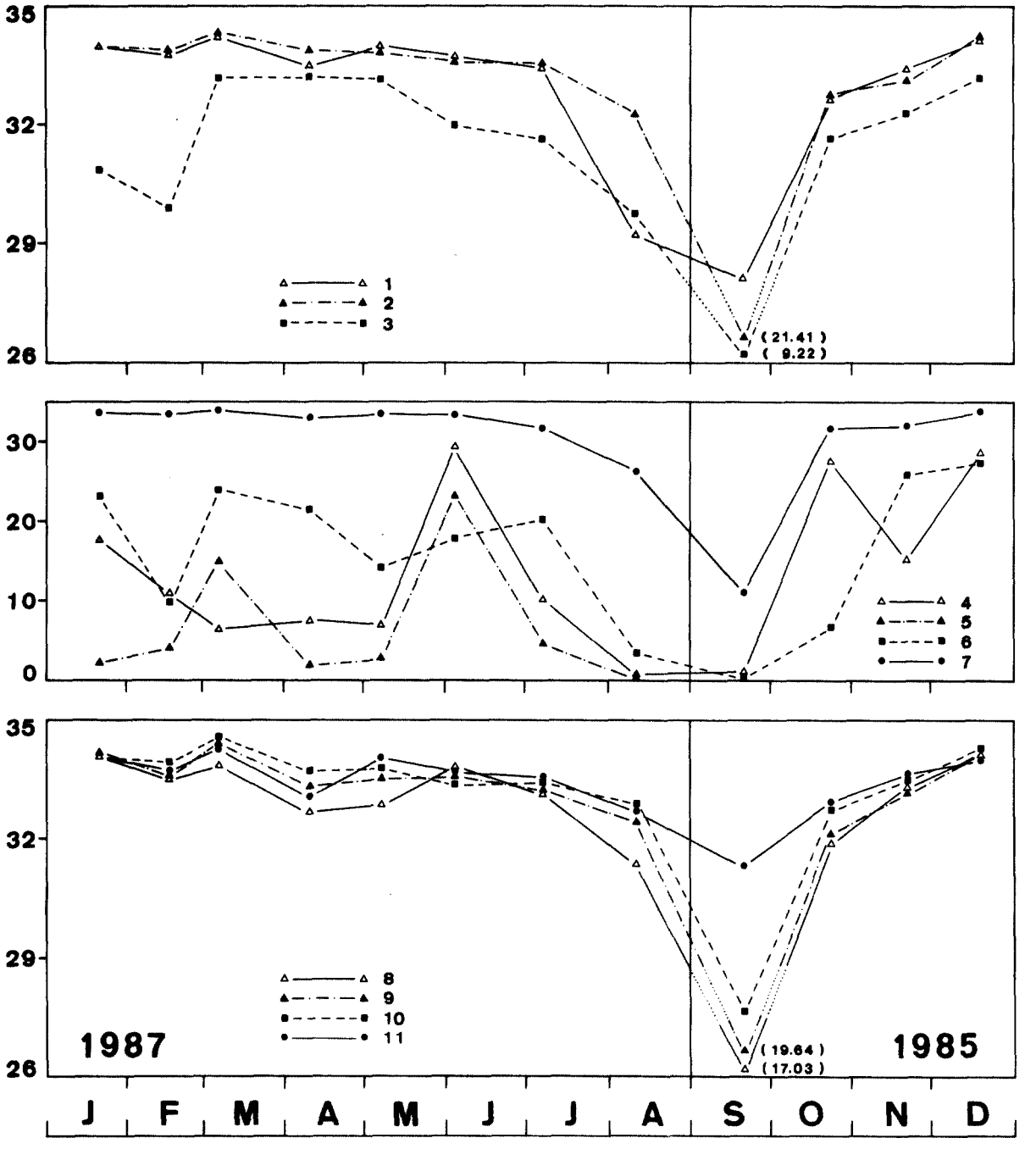

Fig. 5. Annual variation of surface salinity (S‰) at stations 1-11 from January 1987 to August 1987 and from September 1985 to December 1985.

area of the East Sea flows into the Gulf. Salinity increases gradually from summer to winter. This can be explained by latent heat loss, the same as the previously-mentioned phenomenon in the northern coast area. The southern coast area has relatively high salinity compared with the northern area because the southern coast area is less influenced by fresh water inflow.

Variations of density have similar readings along with salinity. The southern coast area has almost no change of density readings in July and August compared with the northern coast area. It should be noted that the southern coast area is regularly influenced by the mass of the East Sea while the northern coast area is only irregularly influenced by the fresh water of the Hyungsan River.

(2) Annual variation

Salinity in 1985 had a low value of 14.20‰ in September as compared with other months of 1985, but salinity in 1985 was higher than readings of 1986 after October.

Salinity of 1986 and 1987 have almost similar readings. On the other hand, salinity in 1986 was lower than readings of 1987 in July. It should be explained that the precipitation of 1986 was heavier to that of 1987. As can be seen, rainfalls (or fresh water) have a very great influence on variations of salinity.

(3) Variation among stations

Doku Beach has low salinity and a deviation of 23.05‰ compared with other stations. This indicates that this reading of salinity is closely related to the fresh water of the Naeng streamlet. Kim (1986) noted that the influence of temperature on salinity could not be disregarded in this area. When stations become gradually more distant from the Naeng streamlet outlet to the East Sea, than salinity increases slowly. On the whole, the southern coast area has higher temperature and lower salinity as against the northern coast area. This indicates that the southern coast area is only indirectly influenced by the East Sea.

3. The central water area

Observation points were set up at stations B and C in order to know the horizontal and vertical characteristics in the central water area.

Station B was located at the central water area of the gulf. The red tide phenomena are frequently observed in this area. The depth is about 26m and the sampling depths were 0,5,10,20 and 25m.

Station C could represent the whole water area since it is located in the heart of the gulf. Frequently traffic of ships is observed and this area is one of the main transporting routes. The depth of water is around 21m and the oceanographic survey was done in the depths of 0,5,10 and 20m.

The variational ranges of salinity and density are as follows; station B has 30.28-34.32‰ and 21.37-26.79, station C has 18.11-34.32‰ and 21.29-26.72, respectively.

(1) Horizontal and vertical variation

Station C has a high variational range compared with station B. This indicates that station C had a lot of influence from fresh water.

In the vertical variations, salinity has similar readings between the upper and lower layer except for a remarkable halocline in August and September. It should be noted that the central water area has the representative characteristics of neighbouring water (Kwak, 1976).

Salinity has a minimum average value in September and October, and gradually increases in November. Salinity reaches its maximum average value (station B, 34.30‰ ; station C, 34.31‰) in February. Exceptionally, the upper layer is high in salinity compared with the lower layer in winter and spring (December 1985 ; February 1986 ; January and March 1987). It should be explained that surface sea water is evaporated by latent heat loss in the dry and cool air, the same as was discussed before.

Generally the upper layer has low salinity compared with the lower layer. The variational range of the surface layer (18.11-34.32‰) is higher than that of the bottom layer (32.88-34.325). This indicates that fresh water which flows onto the surface sea water had much influence on the variation of salinity.

Variations of density have similar readings to salinity readings (Fig. 5. 7). Density has the tendency to increase at the same as the supply of fresh water tends to decrease. Also, both pynocline and halocline are simultaneously formed in the two stations, Station B has a small variational range and a high average value. It should be noted that station B is directly influenced by the East Sea whereas station C is not.

4. The old port area

The old port area which is adjacent to the mouth of the Hyungsan River is Hakjam-dong (station 4), Songdo bridgs (station 5), station H and station I, respectively (Fig. 1). This area represents an extreme case of pollution from

the sewage of Pohang City and the oil of various ships. During periods of survey, the red tide phenomena were frequently observed in this area.

The annual average values of salinity and density in this area are 21.21% and 15.21, respectively.

(1) Seasonal variation

Usually salinity and density have similar readings. The variational range of salinity is not less than 20% (Figs. 2 and 3). In the vertical variation of salinity, station H which is adjacents to the mouth of the Hungsan River is generally lower than station I. This indicates that station I is directly influenced by fresh water stemming from topographic influences.

Salinity and density when average values are compared have a high value is spring. Values slowly decrease in summer (May) and increase abruptly in July. They again suddenly rise in August, drop in autumn and gradually increase in winter. It should be speculated that in the case of July, the value is influenced by rainfall and, in the case of winter, the value is effected by the latent heat loss as previously mentioned.

(2) Annual variation

Figs. 2 and 3 show the vertical variation of salinity. In the case of July, 1986 which had much precipitation and 1987 which relatively had little precipitation strongly influenced the level of halocline of about 3m and 2.5m in station I and H, respectively. The variational range of the layers is regularly below 2‰. If the fresh water is predominant, station I which is located at the mouth of the river is affected by fresh water, but if fresh water is not prodominant, station I is almost not affected by fresh water stemming from topographic influences.

The upwelling phenomena were observed in August 1986, it should be considered that a branch of the Liemann Current which proceeds southward follwing the coast area of the East Sea, intrudes into the gulf, settles down to the bottom of the gulf and flows into the mouth of river. However, this upwelling phenomena was not observed in August 1987. This indicates that the Liemann Current of 1987 compared with that of 1986 was weak.

(3) Variation among stations

The average values of salinity and density appear as follows; Hakjam-dong is 14.91‰ and 10.29, Songdo bridge is 7.24‰ and 4.20, station H is 32.70‰ and 24.22, and station I is 31.30‰ and 23.48, respectively. It should be noted that station 4 and 5 show the characteristics of fresh water affected by the sewage of Pohang City and the river, while in the other stations H appeared the characteristics of sea water provided by the gulf.

5. The POSCO coast area

POSCO coast area contains stations D,E and F (Fig. 1). The facilities of this area were constructed for the purposes of the steel industry. First of all, there are a lot of breakwaters and berths. These facilities interrupt the flow of currents. In addition, various kinds of pollution materials from industrials activities can add to the water conditions or are precipitated. Pollution from ships is also a serious problem. The phenomena of red and black tides are frequently observed.

The annual average values of salinity and density in this area follow ; station D has 32.79‰ and 24.33, station E has 33.24‰ and 24.76, and station F has 33.30‰ and 24.82‰, respectively.

(1) Seasonal variation

Figs. 2 and 3 show the vertical variation of salinity. Station F had halocline at the depth of about 5m in the rainy season in July 1986 compared with station D and E. This indicates that station F is only indirectly effected by fresh water compared with other stations. Station F shows the same characteristics and has a high value compared with other stations in August.

Salinity has an extreme low value in September and rises again in October. This indicates that this area shows the representative vertical variations of neighbouring waters.

(2) Annual variation

The variations of density have same readings along with salinity. Both of station D and E have a well-developed pycnocline contrary to the situation of station F in July each year. All stations appear to show continuously vertical variations. It should be considered that these vertical variation phenomena occur from the frequent comings and goings of various kinds of ships and from the mixing between the surface layer and the bottom layer induced by a strong northwesterly monsoon wind.

(3) Variation among stations

The annual average value of salinity and density in these station are as follows; station D has 32.79‰ and 24.33, station E has 33.24‰ and 24.76 and station F has 33.30‰ and 24.82.

During periods of survey, it was observed that station F is effected by the small quantity of fresh water and has a low temperature. Station D which is adjacent to the

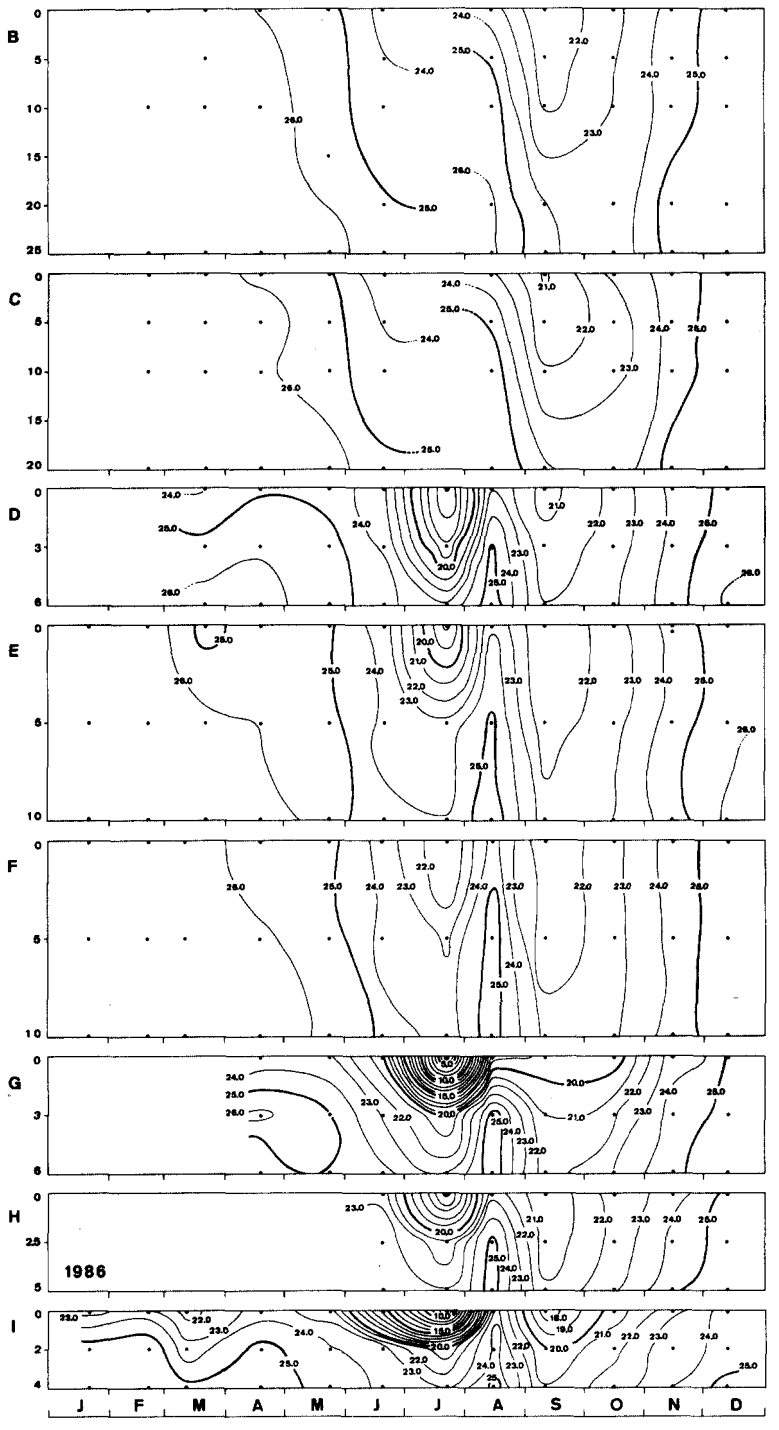

Fig. 6. Annual variation of density at stations B-I during 1986.

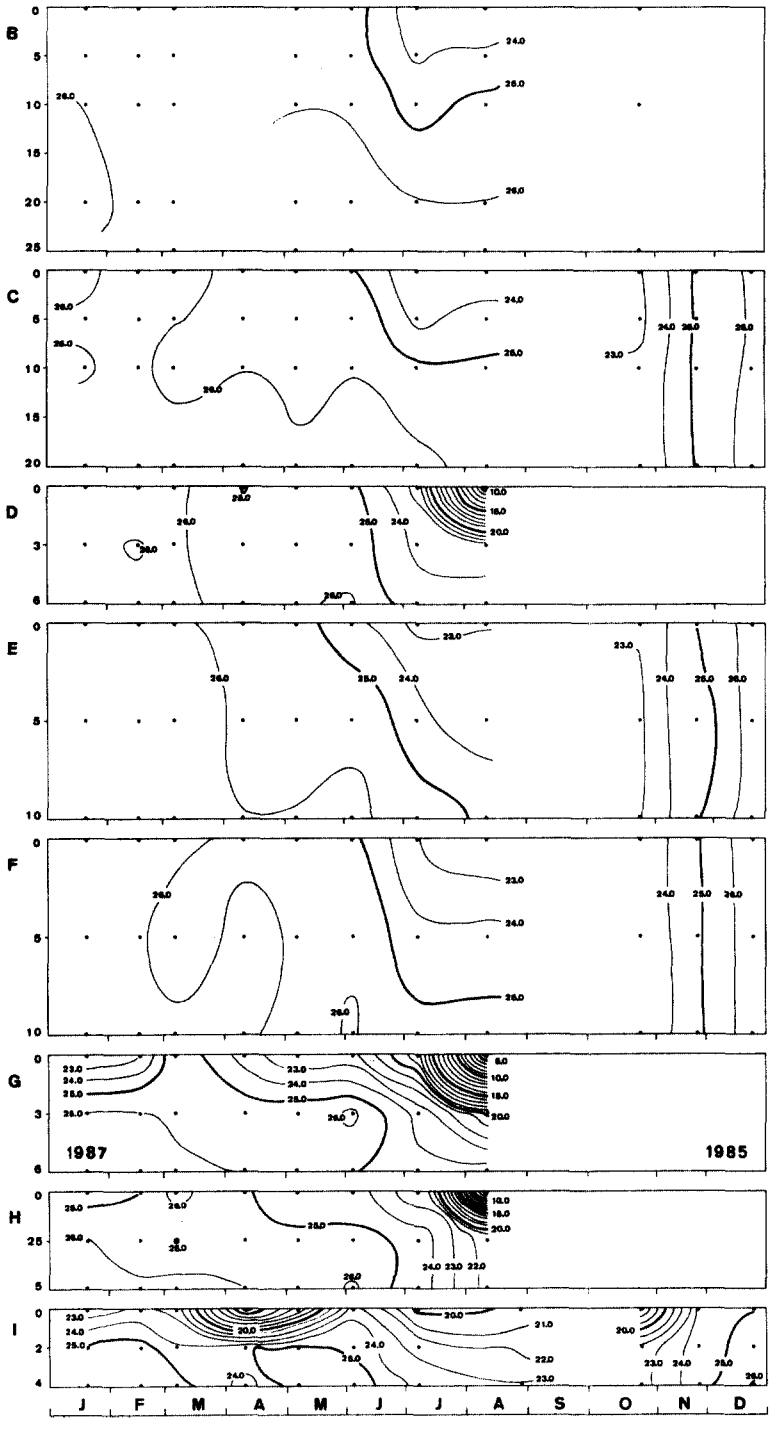

Fig. 7. Annual variation of density at stations B-I from January 1987 to August 1987 and from September 1985 to December 1985.

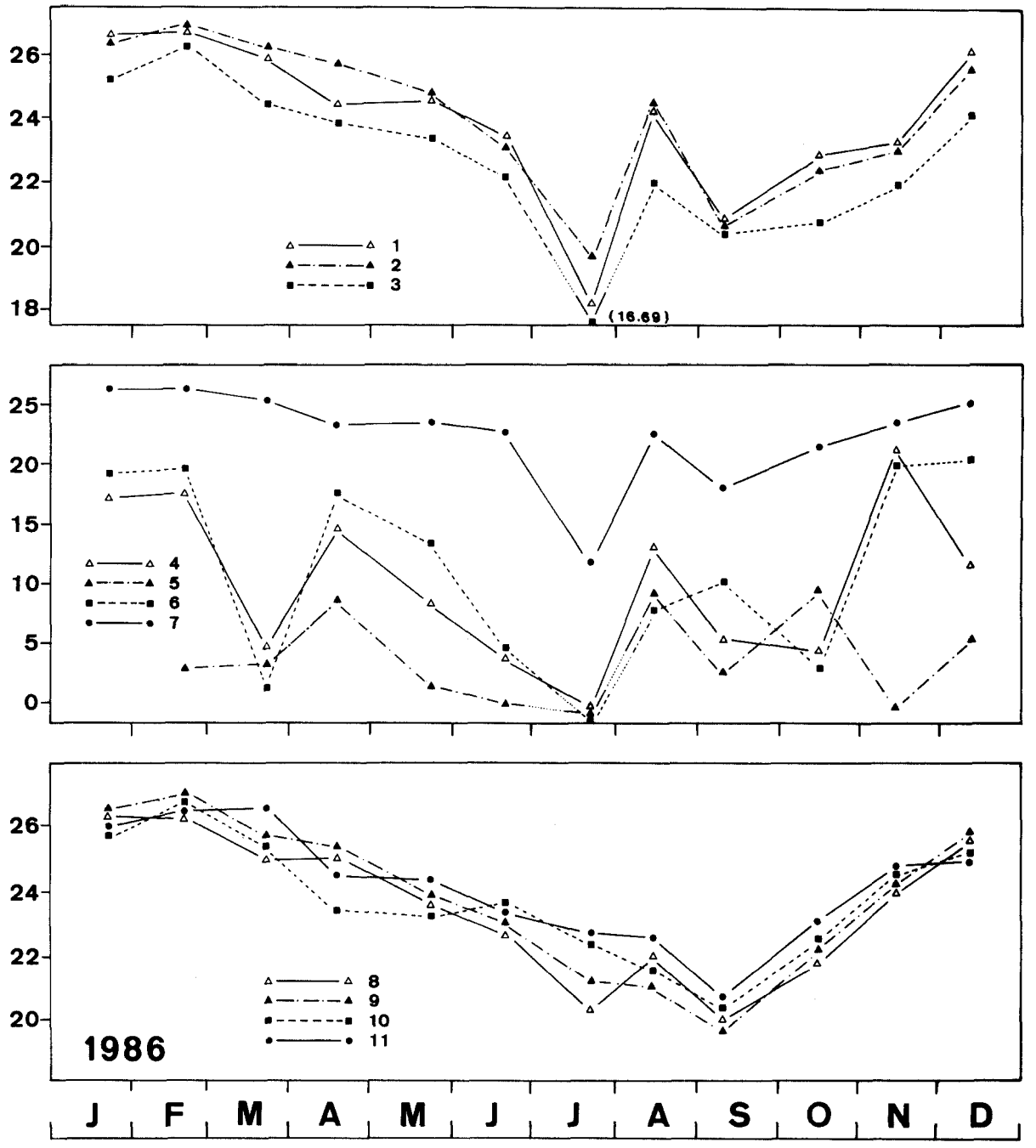

Fig. 8. Annual variation of surface density at stations 1-11 during 1986.

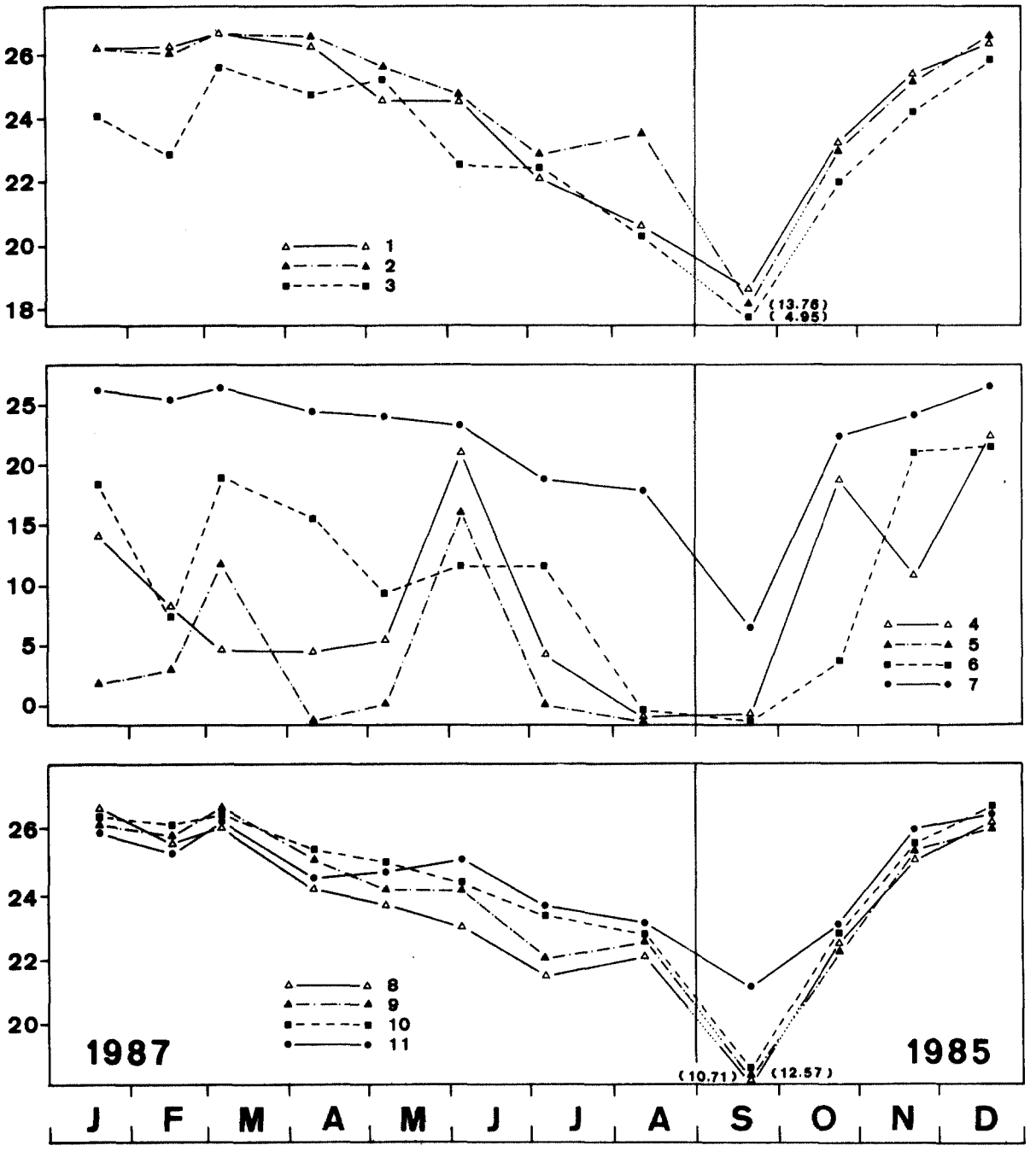

Fig. 9. Annual variation of surface density at stations 1-11 from January 1987 to August 1987 and from September 1985 to December 1985.

Naeng streamlet is influenced by this plethora water, and station E which is adjacent to the gulf is effected by sea water (Kim et al, 1986).

Station D and E have an extreme value of 34.34‰ (surface sea water, February 16, 1987) in winter in the cool and dry season. This result is induced by the evaporation of surface sea water. Station F has a high value of 34.21‰ (August 1986) in summer, it should be explained that radiant heat greatly influences this station compared with the central water area (Kim, 1986).

The variational ranges of density in these stations are as follows; station D,E and F have 26.51-15.88, 26.80-17.89 and 26.80-21.01, respectively. Station D which is located near the Neang streamlet has the largest variation range which is induced by the effects of incoming fresh water.

6. The estuary of the Hyungsan River coast area

Station 6 and G which are located near the estuary of the Hyungsan River adjoin a typical region of mixed fresh water and sea water (Fig. 1). This area acts as an important source of fresh water for the Gulf of Yeongil, influx also includes city sewage and agricultural chemicals mixed which waste water from the plant at the mouth of the river, so the drgree of pollution is very severely heavy.

The annual average value of salinity and density are 23.20‰ and 16.65 in this area.

(1) Seasonal variation

Station 6 displayed the characteristics of fresh water below 2‰ in September, 1985, and in March and July, 1986. The value of density in this station is similar to the value of salinity.

Salinity and density of station G had an extreme low average value in July, 1986, as opposed to the extreme high average value during the period from December 1986 to June 1987. This indicates that the low value is influenced by the effects of fresh water from rainfall, and the high value is influenced by the effects of the evaporation of surface sea water induced by latent heat loss.

In vertical variations, salinity appeared stratified patterns in July 1986 and appeared a homogeneous patterns in almost all season. The upwelling phenomena were observed in this area in August 1986.

(2) Annual variation

Station 6 and G were higher than the average value of salinity in 1987, 1986 and 1985 in order of value reading. The extreme high and low value of salinity and density are as follows; the extreme high value was 34.26‰ and 26.44 in station G at 6m depth in March 1987. The extreme low value was 0.14‰ (September 1985) and 1.49 (March 1986) at station 6.

(3) Variation among stations

The average value of salinity and density are as follows; station 6 and G have 16.97‰ and 11.81, and 32.34‰ and 23.91, respectively. This indicates that station G has the characteristics of sea water, on the other hand, station 6 has the characteristics of fresh water.

7. The coast area of the East Sea of Korea outside the gulf

The coast area of the east sea of Korea is located outside of the pollution-affected area of the gulf, and this area shows a clean water area. This area consists of Ganggeumri (station 10) and Gurong-po (station 11), (Fig. 1). This area provides a good opportunity to study and compared readings between the gulf and the East Sea.

The annual average, maximum, and minimum value of salinity and density are 33.22‰ and 24.36 ; 34.51‰ (station 10, March 1987) and 26.76 (station 10, February 1986) ; and 27.66‰ (station 10, September 1985) and 18.48 (station 10, September 1985), respectively.

(1) Seasonal variation

Figs. 3, 4 show an average value of 34.16‰ in winter (from December to March), value of 33.50‰ in spring, and a low value in July.

This area has similar values as compared with other areas. This indicates that this area is only indirectly affected by waste waters from Pohang City and the mammoth iron industry works.

(2) Annual variation

This area had relatively a low value in September 1985 and in 1986 because of the direct effect of the waters of the East Sea of Korea.

(3) Variation among stations

The salinity of the two stations have similar readings, but salinity has a low value and high deviation in Ganggeum-ri compared with Gurong-po. This indicates that Ganggeum-ri has a relatively high temperature (Kim et al, 1988).

This area appears to have high salinity as against the northern coast area and southern coast area. It should be noted that this area is affected by the East Sea of Korea.

T-S diagram

Fig. 10 shows relations between water temperature and

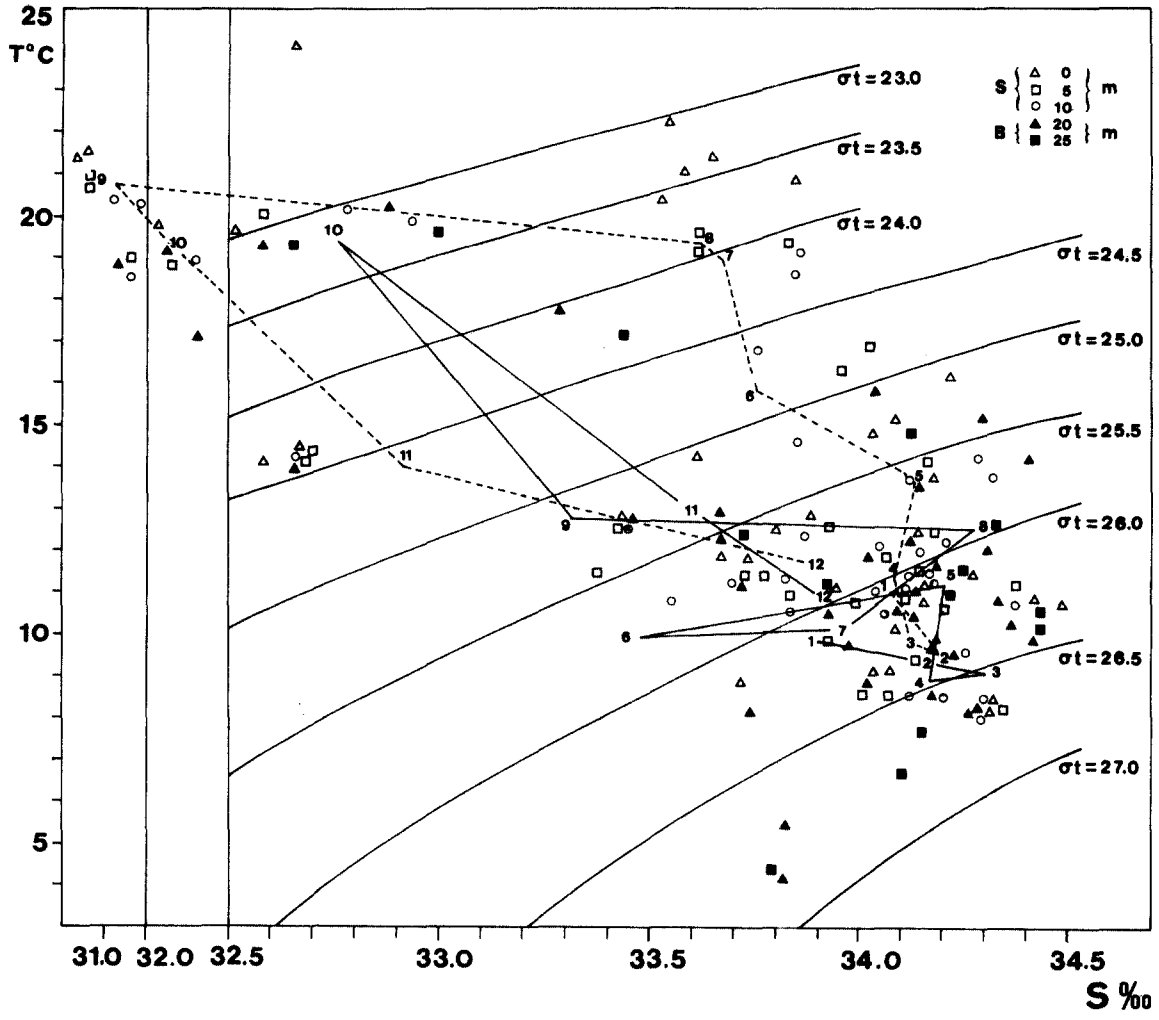

Fig. 10. Relation between water temperature and salinity in the central water area (station B and C).

salinity in the central water area (station B and C). Two inclined lines indicate a monthly mean values both the surface layer (the depth between 0m and 10m) and the lower layer (the depth between 20m and 25m).

Points were widely dispersed from the left-upper portion to the right-lower portion. These phenomenon appeared a similarity that was contrary to each other.

In monthly variation, the deviation values of salinity between the uppr and lower layer were large. Especially, Thermal stratification was remarkably developed in July, August and September. Usually, values of salinity in the surface layer were low, but variations of salinity were large.

Both salinity of 34.1% and water temperature of 12°C were mainly appeared through the whole periods except only August, September, October and November.

Conclusion

The oceanographic characteristics in the Gulf of Yeongil were studied by using salinity and density obtained "in situ" from September 1985 to August 1987.

Variations of salinity is influenced by inflow of fresh water, evaporation and solar-radiation, etc.. However the most important parameters among them are precipitation and the fresh of the Hyungsan River. The value of salini-

ty of increases gradually but the incline reading grows radidly from the head to the mouth in the gulf.

The coast area outside the gulf has an extreme high value compared with other coast areas, and has a low value coming from outside of inside in the gulf.

Salinity and density of the northern coast area have a high value as opposed to those readings of the southern coast area. Salinity and density of both the old port coast area (station H and I) and the mouth of the Hyungsan River (station G) are 21.21‰ and 15:20 ; 23.12‰ and 16.15, respectively. These areas show the characteristics of brackish water.

The water mass in these areas shows typically salt wedge forms which divide the heavy lower and the light upper layer.

Density is influenced directly not only by salinity and temperature but also indirectly by climate and fresh water Variation of density is largely influenced by salinity in a brackish water area, and by temperature in sea water areas. The deviations of variation of density have similar readings excepting in station D, G and H which are affected by brackish water. Usually the annual average values of all stations are influenced by fresh water and the values increase gradually from the head to the mouth in the gulf.

Acknowledgemetns

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