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Oceanic structure in the vicinity of a seamount, the Komahashi Daisan Kaizan, south of Japan

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Abstract : The hydrographic observations in the vicinity of a seamount, the Komahashi Daisan Kaizan at west of Izu Ridge south of Japan have been carried out in July 1989. It is shown that there exist horizontal gradients of isotherms and isohalines in a layer deeper than the top of the seamount, which is similar to the structures at Daini Kinan Kaizan, Komahashi Daini Kaizan and Tosa–Bae, south of Japan. Various microstructures of the salinity fields are observed over the top of the seamount, which suggests occurrence of interleaving of different waters. Thickness of salinity minimum water less than 34.2 psu is relatively thin over the top of the seamount in comparison with that in the area far from the top of the seamount, suggested that the thin salinity minumum layer is formed by larger vertical mixing over the top of the seamount and/or by the topographic effect of the seamount which forces less saline water to flow along the isopleth of depth of the seamount. T–S relations of the intermediate water in the vicinity of the Komahashi Daisan Kaizan is close to those at south of the Izu Ridge rather than to those at west of the Izu Ridge. It is indicated that the less saline water over the vicinity of the Komahashi Daisan Kaizan comes from south of the Izu Ridge, flowing along the bottom contour of the Izu Ridge.

1. Introduction

Influence of the topographic effect of seamounts on the temperature, salinity and velocity fields has been studied from various view points. On the basis of the geophysical fluid dynamics, topographic effects of seamounts depend on the vertical structure of the Taylor Column formed on the seamounts (*e.g.*, PEDLOSKY, 1979 ; GILL, 1982), which have been investigated from observational and theoretical view points (HOGG, 1973, 1980 ; JOHNSON, 1977).

Various observations have been carried out in vicinity of some seamounts south of Japan. FUKASAWA and NAGATA (1978 ; 1980) observed the oceanic structure near the Shoal Kokushousone located in southwest of Kyushu. Upwelling along the northern slope of the shoal was shown by the temperature observation in February and October 1975 and December 1976 (FUKASAWA and NAGATA, 1978), while upwelling along southern slope was detected in June 1977 (FUKASAWA and NAGATA. 1980). KONAGA *et al.* (1980) observed that the detached cold eddy from the large meander of the Kuroshio, "Harukaze" (KONAGA and NISHIYAMA, 1978), thends to stay over the Daini Kinan Kazan (Fig. 1). SEKINE and HAYASHI (1993) observed a horizontally coherent microstructure over this seamount. YOSHIOKA *et al.* (1986) observed oceanic condition over the Tosa-Bae and showed that the temperature field in the layer shallower than 300 m has a frontal structure, whereas a cold dome–like structure is observed below 300 m. SEKINE and MATSUDA (1987) and SEKINE *et al.* (1994) observed a coupled warm and cold waters in the upper layer shallower than 500m. Furthermore, SEKINE *et al.* (1997) observed hydrographic conditions around Komahashi Daini Kaizan located in the Kyushu–Parau Ridge southeast of Kyushu (Fig. 1).

The present study is directed toward oceanic

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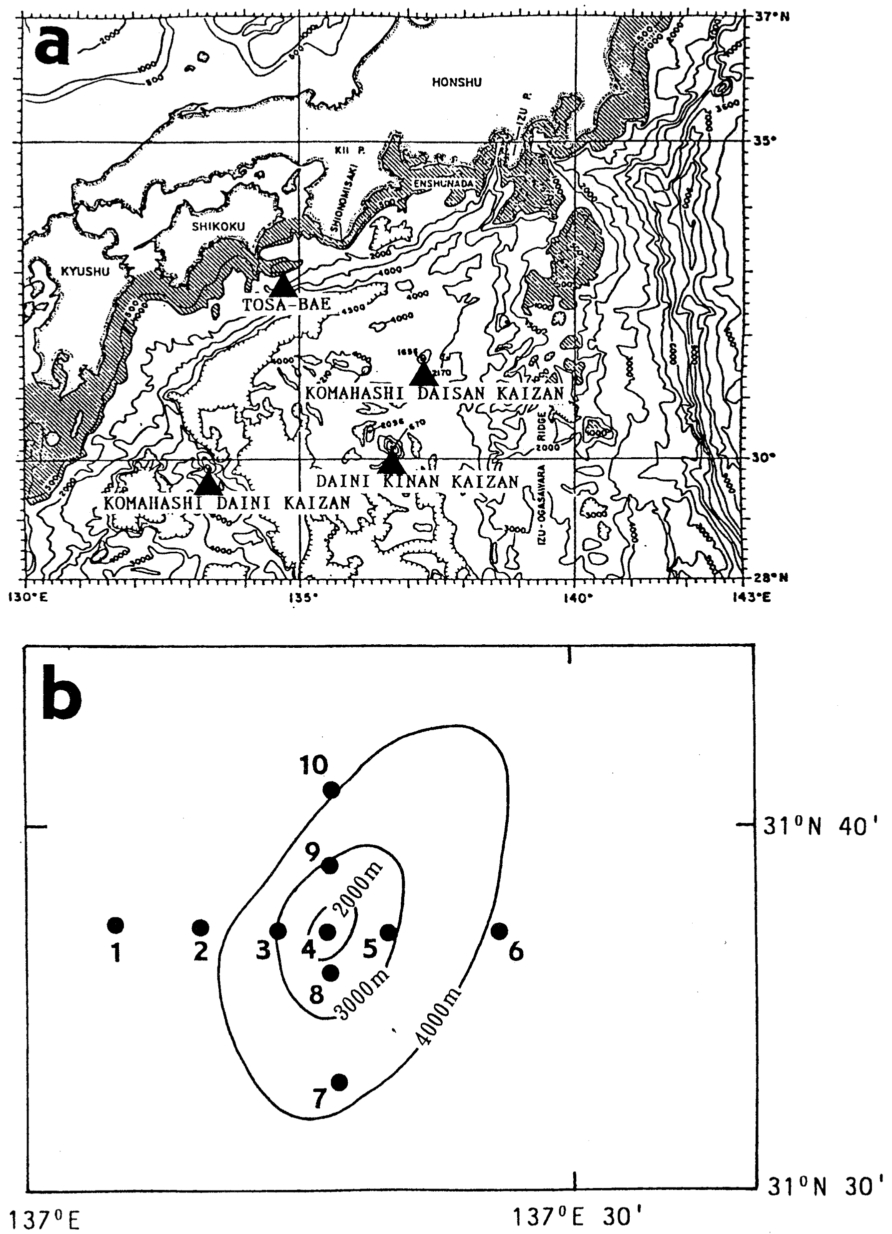

Fig. 1. (a) Isopleth of depth south of Japan (after TAFT, 1972) and locations of main seamounts so far observed. (b) Observational points of CTD of the present study in the vicinity of Komahashi Daisan Kaizan. Isoplethes of depth are also shown.

conditions in the vicinity of the Komahashi Daisan Kaizan located at a west of the Izu Ridge in the Shikoku Basin south of Japan (Fig. 1). The top of the seamount has a depth of 1696 m. Since main axis of the Kuroshio passes over or near this seamount in period of large meander path, there is a possibility that this seamount has influence on the Kuroshio flow.

Salinity minimum layer is observed in the Kuroshio region south of Japan (*e.g.*, SEKINE *et al.*, 1991). This less saline water in the salinity minimum layer corresponds to North Pacific Intermediate Water (*e.g.*, REID, 1965 ; TALLEY and NAGATA, 1991). If a topographic effect of this seamount is not negligible, the less saline water flowing over the vicinity of the seamount is forced to flow along isopleths of the seamount.

However, up to this time, no confined observations has been carried out focusing on the topographic effects of the Komahashi Daisan Kaizan. Then, we have observed temperature and salinity fields in the vicinity of this seamount in July 1989. Results of this observation are presented in this paper. In the following, details of the observation will be mentioned in the next section. Results of the observation will be described in section 3. Summary of the main results and discussion will be made in section 4.

2. Observations

The hydrographic observations by CTD were carried out on 25 and 26 in July 1989 by use of the Training Vessel Seisui-maru of Faculty of Bioresources of Mie University. The locations of the observational points are shown in Fig. 1b. Unfortunately, because of the trouble in the output system of CTD occurred at the station 2, the exact memory has not stored. However, as their record memory was printed out during the observation, their gross features were used in the data analysis.

The main axis of the Kuroshio during the later half of July 1989 presented by Maritime Safety Agency is shown in Fig 2. No meander path was formed and the distance between this seamount and main axis of the Kuroshio was relatively large. Therefore, topographic effect of this seamount on the Kuroshio flow is suggested to be relatively small in comparison with a period of large meander path in which main axis of the Kuroshio flows over this seamount. Thus, our focus is mainly placed on the influence on the less saline water in the salinity minimum layer, which corresponds to North Pacific Intermediate Water.

3. Results

The vertical distributions of temperature and salinity along two observational lines are shown in Fig. 3. Seasonal thermocline and halocline are formed in a surface layer shallower than 50 db. A thich subtropical mode water (MASUZAWA, 1969 ; 1972) with temperature of 18° C and salinity of 34.8 psu is detected in depths of 50 db-500 db. Along the meridional obsverational line, weak uplift of the isotherms are detected over the seamount in depths of 1200 db-1500 db. Since clear vertically coherent and/or vertically evanescent structures of the isotherms and isohalines are not seen in these variations, these vertical shifts are probably due to internal waves.

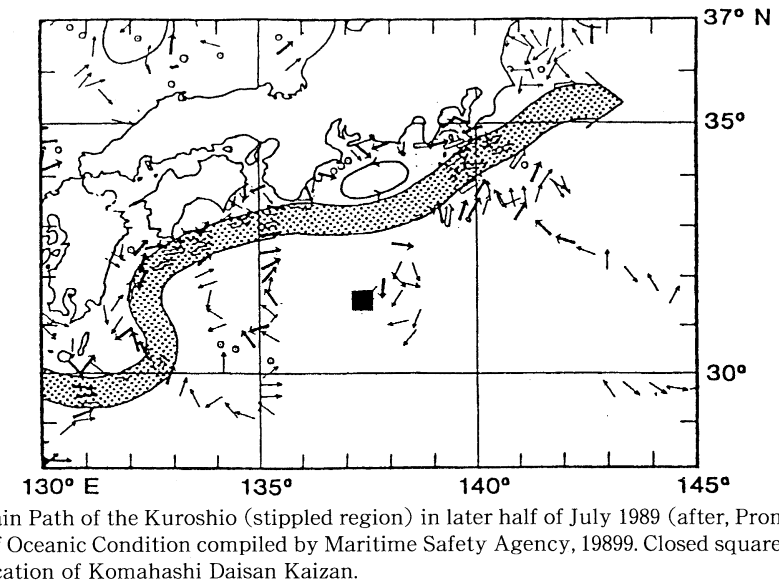

Fig. 2. Main Path of the Kuroshio (stippled region) in later half of July 1989 (after, Prompt Report of Oceanic Condition compiled by Maritime Safety Agency, 19899. Closed square shows the location of Komahashi Daisan Kaizan.

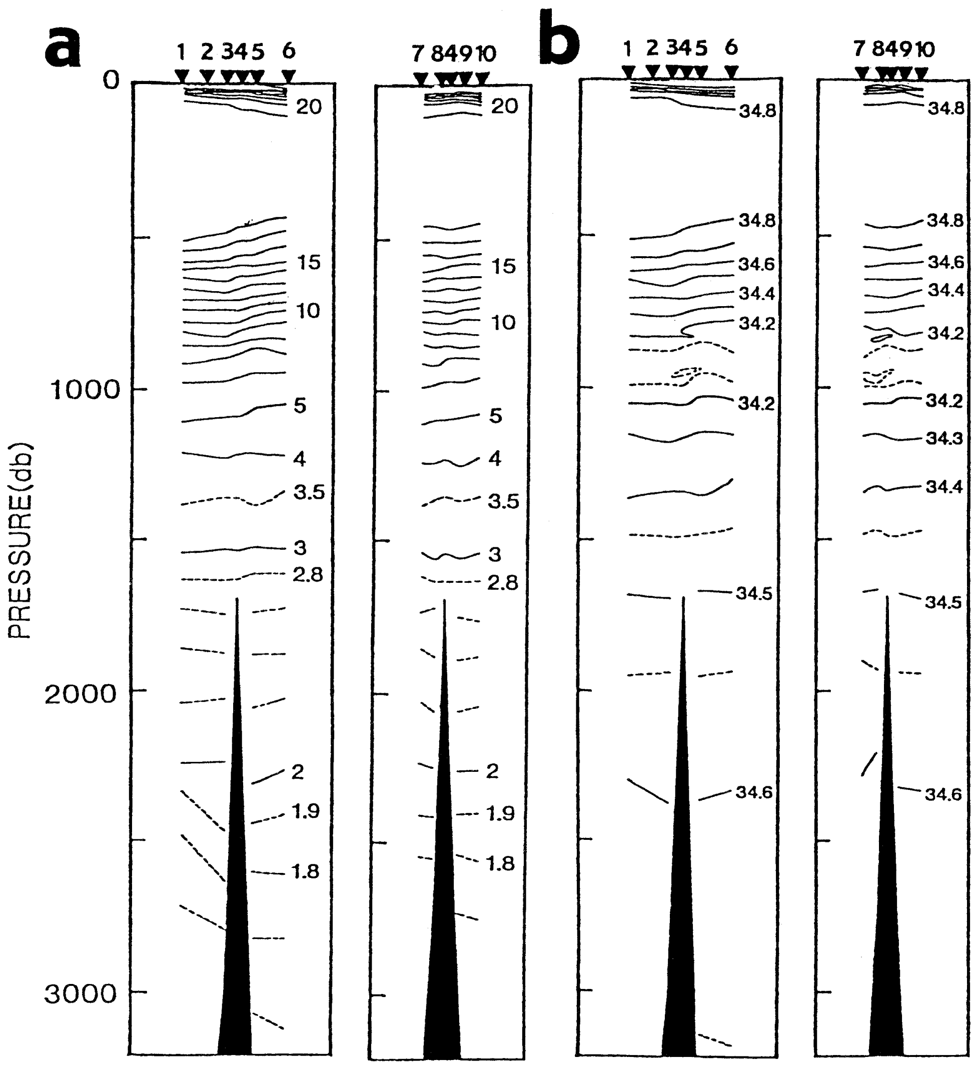

Fig. 3. (a) Temperature (in degree) and (b) salinity (in psu) sections along two observational lines. Locations of the observational stations are shown on the top.

Vertical shifts of the isotherms and isohalines are detected in the layers deeper than the top of the seamount, which are similar to the cases of Daini Kinan Kaizan (SEKINE and HAYASHI, 1993) and Tosa-Bae off Shikoku (YOSHIOKA *et al.*, 1986 ; Sekine and Matsuda, 1987 ; SEKINE *et al.*, 1994) and Komahashi Daini Kaizan (SEKINE *et al*, 1997). It is seen from Fig. 3 that downward shifts of the isotherms and isohalines are dominated at depths of 2400 db–2800 db in west of the seamount. Namely, warm and less saline water exists over the side slope of this seamount. However, weak upward shift of isotherms and isohalines are detected in the layer deeper than 3000 db, details of the water distribution are unclear.

The salinity minimum layer was observed at the depths of 800 db–1000 db. Isohalines in the salinity minimum layer are perturbed over the top of the seamount. To see this more clearly, vertical distribution of salinity in the salinity minimum layer is shown in Fig. 4. Thickness of

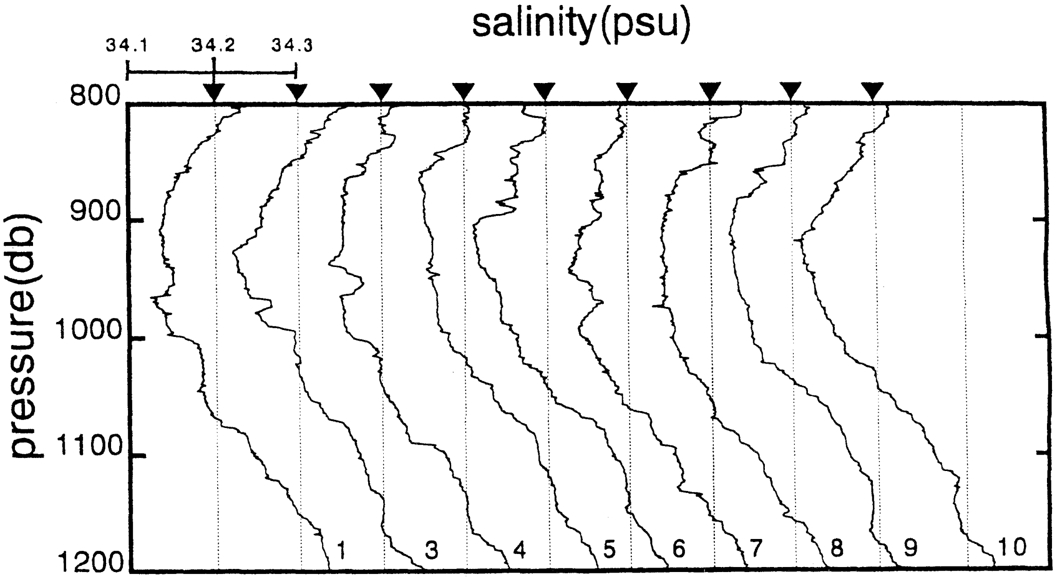

Fig. 4. Vertical distribution of salinity around the salinity minimum layer.

less saline water than 34.2 psu is relatively thin at stations 3, 4 and 5, while the thickness of the less saline water is thick at stations 1, 6 and 7. The former stations 3, 4 and 5 are located near the top of the sea mount (Fig. 1) and the latter stations 1, 6 and 7 exist relatively far from the top of the seamount. It is suggested that the thin layer of less saline water over the top of the seamount is formed by larger vertical mixing and/or by the topographic effect of the seamout which forces less saline water to flow along isopleth of depth of the seamount.

Various kinds of microstructures are seen in Fig. 4. Thin saline water intrusions at depths of 970–990 db at station 3 and 940–960 db at station 4 are detected, while a thick and complicated saline water intrusion at depths of 810–900 db is seen at stations 6 and 7. Although the details of the formation process of the microstructures of the salinity distribution are not well analyzed, occurrences of the horizontal and/or oblique interleaving of different water are suggested.

T–S diagram near the salinity minimum layer is shown in Fig. 5. Here, two envelopes are also plotted to see the pathorigin of water. One envelope in relatively saline area corresponds to the T–S relations at observational stations in west of the Izu Ridge (Fig. 6) observed in summer of 1993 and 1994 (SEKINE *et al.*, MS). The other envelope in less saline water corresponds to the T-S relations at south of the Izu Ridge observed in October 1985 (SEKINE *et al.*, 1991). Because the less saline envelope corresponds to North Pacific Intermediate Water (*e.g.*, REID, 1965; TALLEY and NAGATA, 1991), the less saline water is originated from the subarctic circulation in North Pacific locating northeast of the Izu Ridge. It is shown from Fig. 5 that the T–S relations in the salinity minimum layer is relatively close to the envelope of less saline water observed at south of the Izu Ridge (Fig. 6). It is suggested from the T–S relations that a salinity minimum water over the vicinity of the Komahashi Daisan Kaizan includes relatively large volume of a less saline water which comes from south of the Izu Ridge.

4. Summary and discussion

The hydrographic observations in the vicinity of the Komahashi Daisan Kaizan south of Japan were made by the Training Vessel Seisui maru of Mie University in July 1989. Main results of the observations are summarized as follows.

(1) Vertical shifts of the isotherms and

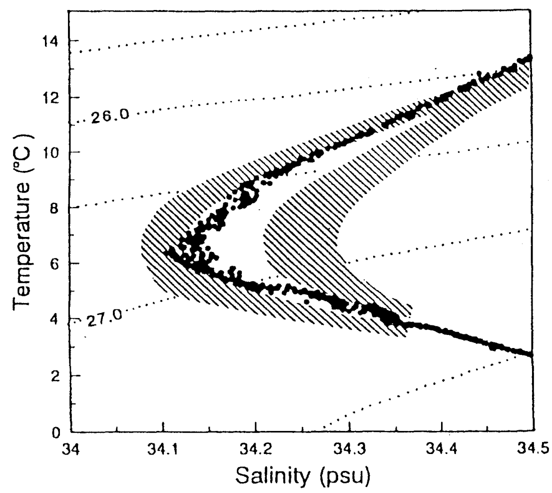

Fig. 5. T–S diagrams near the salinity minimum layer. Left (right) oblique lines shows the envelope of T–S diagram of water at stations in south (west) of the Izu Ridge shown by closed squares (closed circles) in Fig. 6.

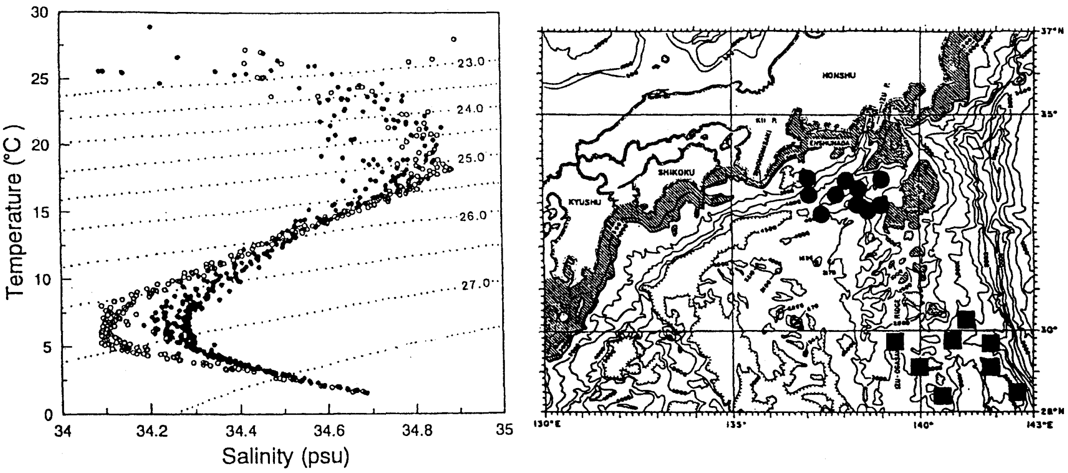

Fig. 6. T–S diagram of the Kuroshio water at west of the Izu Ridge (closed circles) and at south of the Izu Ridge (open circles). The observational stations of the west and south of the Izu Ridge are shown by closed circles and closed squares, respectively in the right.

isohalines are observed in the layers deeper than the top of the seamount, which is similar to cases of other seamounts in the Shikoku Basin shown in Fig. 1. Various kinds of microstructures of the salinity distribution are observed in the salinity minimum layer, which suggests occurrence of the horizontal and/or oblique interleaving of two waters with different salinity.

(2) The salinity minimum layer was observed at the depths of 800–1000 db. Thickness of salinity minimum water less than 34.2 psu is relatively thin over the top of the seamount, which is suggested to be formed by larger vertical mixing and/or by the topographic effect of the seamout, which forced less saline water to flow along isopleth of depth of the seamount.

(3) The T–S relations in the vicinity of the Komahashi Daisan Kaizan are relatively close to those at south of the Izu Ridge rather than those at west of the Izu Ridge. From this, it is

indicated that a less saline water over the vicinity of the Komahashi Daisan Kaizan comes from south of the Izu Ridge.

It is noted from Figs. 5 and 6 that a less saline water over the vicinity of the Komahashi Daisan Kaizan dominantly includes a water which comes from the south of the Izu Ridge. Because the less saline water at south of the Izu Ridge comes from the subarctic circulation in North Pacific, it is suggest that the less saline water comes to the Shikoku Basin after going around the bottom topography of the Izu Ridge. YANG *et al.*, (1993a, b) showed that a less saline Oyashio Water goes over the ridge into Sagami Bay in the northern area of the Izu Ridge. However, since less saline water is not observed in west of the Izu Ridge, which is shown by saline envelope shown in Fig. 6, there is a possibility that almost less saline water in the Shikoku Basin comes from south of the Izu Ridge going around south of the Izu Ridge.

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The solubility of calcite in seawater solution of different magnesium concentrations at 25°C and 1 atm total pressure: A laboratory re-examination

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Abstract: The effect of magnesium ion concentration and the degree of saturation of calcium carbonate in artificial seawater solution (ASW) upon the equilibrium states of calcium carbonate solid has been studied. The apparent solubility products of pure calcite, when exposed to different magnesium–to–calcium concentration ratios in ASW increase with the increase of magnesium ion in the test solution. Their solubility values further increase by increasing the degree of supersaturation at the same magnesium concentration in ASW. The increase of surface areas, that are exposed to the same volume of the solution under the same condition tend to lower the values of the apparent solubility products. This may indicate a sort of shift from kinetic steady–state to probably a thermodynamic equilibrium. The thermodynamic solubility products that are estimated from the ion association model and the activity of calcite and magnesite in the test ASW show that the activity coefficient of magnesite is higher than that of calcite, which indicates that a nonideal solid solution is formed.

1. Introduction

The degree of saturation of seawater with respect to calcite is an important parameter for the prediction of precipitation and dissolution of calcium carbonate mineral in aquatic environment. Although, some natural waters such as marine surface seawater and pore waters are reported to be supersaturated with respect to calcite(WEYL, 1961; CLOUD, 1962; SCHMALZ and CHAVE, 1963; BERNER , 1966a; PLATH *et al*., 1982; MUCCI and MORSE, 1984; WALTER and MORSE, 1984) there are no inorganic precipitation of $CaCO_{3(s)}$ observed and surprisingly, the availability of fine–grained size $CaCO_{3(s)}$ does not change the growth of cementation fabric (BATHURST, 1964, 1974). The presence of metastable calcite phases indicates that either a lack of equilibrium (KRAUSKOPF, 1967) or a compositional thermodynamic equilibrium exists with respect to solid carbonate coating phase (WOLLAST and REINHARD-DERIE, 1977; PYTKOWICZ and COLE , 1979; KONIGSBERGER and GAMSJAGER, 1990).

The retention of supersaturation of natural water and the very slow diagenetic transformation of sediments led many investigators to study the influence of organic and inorganic additives upon the chemical and physical behavior of calicium carbonate minerals (PYTKOWICZ, 1965; JACKSON and BISCHOFF , 1971; SUESS, 1970, 1973; RUSHDI *et al*., 1992).

The magnesium ion in natural seawater is the third major ion in seawater and it is five times the concentration calcium ion. It is directly involved in the formation of $CaCO_{3(s)}$ solid. In marine environment natural calcite contains a range of magnesium in solid solution which is usually named magnesian calcite.

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The skeletal magnesian calcite in biogenic hard parts and marine magnesian calcite in cements are the most important occurrences of these phase (SILLIMAN, 1846; CHAVE, 1952, 1954a, 1954b, 1981; LAND, 1967; SCHMALZ, 1967; PIGOTT and LAND, 1986; ANDERSON and DYRSSEN, 1987; BUSENBERG and PLUMMER, 1989). The most important contributors of skeletal magnesian calcite to shallow water marine sediments are the skeleton of calcareous red algae, benthic foraminifera, bryozoans, echiniods and barnacles (CHAVE, 1981).

Different magnesian calcite mineral have different solubility in solution and it was shown that their solubilities increases with the increase of magnesian fraction in calcite (CHAVE *et al.*, 1962; LAND, 1967; PLUMMER and MACKENZIE, 1974; BERNER, 1975; THORSTENSON and PLUMMER, 1977; MORSE *et al.*, 1979; SCHOONMAKER, 1981; KOCK and DISTECHE, 1984; MUCCI and MORSE, 1984; PIGOTT and LAND, 1986). The values of apparent solubility products of calcite in seawater of 34.8‰ salinity and 25℃ were reported to be between 4.24×10^{-7} to 5.94×10^{-7} $mole^2 kg^{-2}$ SW. (CLOUD, 1962b; MOLLER and PAREKH, 1975; MACINTYRE and PLATFORD, 1965; PLATH, *et al*., 1982; MUCCI and MORSE, 1984). It is believed that the surface area of the mineral that is exposed to the solution plays an essential role on the equilibrium conditions (WOLLAST and REINHARD-DERIE., 1977; WOLLAST and PYTKOWICZ, 1978; PYTKOWICZ and COLE, 1979; MACKENZIE *et al.*, 1982).

The equilibrium states between calcium-magnesium carbonate mineral and aqueous solution at a given temperature and pressure are still ambiguous. It is shown that the stationary states of calcium carbonate in presence of Mg^{2+} in solution are reaction-rate and kinetically controlled(WEYL, 1967; BERNER, 1978). To explain the equilibrium state of calcite an stoichiometric saturation model is developed for non-variable solid phase(THORSTENSON and PLUMMER, 1977). They show that magnesian calcite with <5 mole % $MgCO_3$ is controlled by thermodynamic equilibrium and the occurrence of other compositions is a kinetic control. It has also been suggested (WOLLAST and REINHARD-DERIE, 1977; PYTKOWICZ, and COLE, 1979) that there is no single thermodynamic phase that is an stable one the presence of solid solution. It is also stated that, magnesiam calcite is governed by activity products of $({}^{a}Ca^{2+})$ $({}^{a}CO_3{}^{2-})$ rather than (Mg^{2+})-to-(Ca^{2+}) in aqueous phase(MACKENZIE and PIGOTT,1982; RUSHDI, 1992).

The purpose of this work is to re-examine the effects of various magnesium concentrations, at two different degree of saturations with respect to calcite seeds having different surface areas in artificial seawater, upon the apparent solubility products of calcite. The ionic strength is to be maintained constant at a temperature of 25℃. The ion association model is used in conjunction with the mole fraction of $CaCO_{3(s)}$ in the calcite overgrowth to predict the thermodynamic solubility product of magnesian calcite in the test solution.

2. Experimental procedure

Experiment

(Mg^{2+}), (Sr^{2+}) and (H_3BO_3)-free artificial seawater, ASW, was prepared following the procedure of KESTER *et al.*, (1967). The ASW, which had an ionic strength of 0.526M, was equilibrated with the laboratory pCO_2 for about two days by bubbling air through the solution. The bubbling was stopped when the measured pH was stable and did not change by further bubbling. The concentration of (Ca^{2+}) in this solution was 9.754 mmole kg^{-1} ASW. Various amounts of magnesium were added, from prestandardized stock solution by Mohr titration (BLADEL and MELOCHE, 1957), to prepare solutions with (Mg^{2+})-to-(Ca^{2+}) concentration ratios of 1, 2, and 5. Different amounts of pre-dried reagent grade NaCl were added to these prepared solutions to maintain the ionic strength of 0.718M. Each solution was kept in a closed bottle and its pH was measured every 24 hours, it only changed by ±0.008pH unit. It was noticed that the pH of these solutions decreased with increasing magnesium concentrations.

A reaction cell was constructed from a glass beaker with a water jacket for the determination of the solubility products of calcite in ASW of different (Mg^{2+})-to-(Ca^{2+}) concentration ratios and constant ionic strength of 0.718 at 25℃. The cell which had a volume of 103.76

± 0.03 ml was described by RUSHDI, (1993).

The calcite seeds used in this experiment were reagent grade synthetic calcite (J.T. BAKER), which were washed with double deionized distilled water (DDW) three times, filtered and dried at 110–130℃ for about four hours, then they were kept in vacuum desiccate after cooling down. The x-ray diffraction showed that they were pure calcite by $2\theta = 29.4°$. The specific surface area of calcite seeds was estimated from its density and the seed mean volume, which was determined by SEM images. It was estimated that the specific area was $0.589 \pm 0.053\ m^3g^{-1}$.

The combination electrode (Radiometer GK2401C) was calibrated with NBS buffers, 185f (pH=4.006 at 25℃) and 186- I -c and 186-II-c (pH=7.415 at 25℃). The slope of the electrode was determined following the instruction in PHM64 Research pH meter Operating Instruction. Usually the slope was $99.00 \pm 0.21\%$.

Before each experiment, the initial total alkalinity of each test solution was measured by Gran titration method (GRAN, 1952; DYRSSEN and SILLEN, 1967; MEHRBACH, *et al.*, 1973) and by single-acid addition (ANDERSON and ROBENSON, 1946) which was developed by CULBERSON *et al.*, (1970) to a pH of 4.15 ± 0.10. The standard deviation of the total alkalinity determination by both method was $\pm 5.8\ \mu eq\ kg^{-1}$ASW. The initial pH was also measured for each test solution. The initial total carbon dioxide $\Sigma CO_{2(i)}$, was calculated from these two known parameters by using the values of first and second apparent dissociation constants of carbonic acid at different magnesium concentration described by (RUSHDI and CHEN, 1995).

The reaction cell was completely filled with the test solution and the combination electrode was allowed to equilibrate until the measured pH changed by less than 0.003 pH unit per hour at 25℃, because the drift of the electrode was measured and found to be 0.003 pH per hour. The experiments were carried out in a water bath (Aminco Constant Temperature bath #4-8605) at 25.00 ± 0.05℃. Two different degree of saturation were obtained by selecting two pH values: pH=8.1 and pH=8.6 which were achieved by adding drops of 0.1N NaOH to the test solution from a syringe with a long needle through the hole in the stopcock while stirring. Then the piston was pushed half-way into the solution to fulsh some of the excess solution. The pH was recorded every five minutes until three successive readings were the same then the calcite seeds were added. The required weight of calcite seeds was placed in 2.5 ml Hamilton syringe with a long needle, then stirring was stopped and through the hole of the stopcock about 1.5 ml of ASW of the test solution was withdrawn into the syringe to form a slurry of calcite, which was then injected slowly into the solution without stirring. This step was done carefully to avoid any bubble trapping in the cell, and it was done at least three times to insure that all the amount of calcite was delivered into the solution and settled to the bottom of the raction cell. The piston was pushed all-the-way down to displace the excess volume of ASW through the stopcock hole. The stopcock was immediately closed to prevent CO_2 exchange and the solution was stirred. The pH was recorded with time until it reached steady-state. The steady-state value was assumed to be achieved when the change in pH was again less than 0.003 pH unit hr^{-1} assuming that our pH measurement was better than 0.008 pH unit. Although, it took between 6 to 8 hours to reach a steady-state in experiments of high solid to solution ratios, all the experiments were run for at least 48 hours. After reaching the steady-state equilibrium the solution was filtered through 0.45 μM Millipore filter papers. The unwashed seeds were collected, dried and stored for calcium and mangesium content determinations. Atomic adsorption analysis, AA, was used to determine the final (Ca^{2+}) concenrations. The concentration of calcium at equilibrium of each solution was determined by diluting the solution to obtain a calcium concentration of about 1.00 ppm. The original test solution was used as a standard, from which two dilutions with calcium concentration of 1.25 ppm and 0.90 ppm were prepared. Excess KCl (about 1000 ppm) was added to each solution as an ionizing suppressant to avoid the ionization of excess NaCl which may affect the $(Ca^{2+})$and (Mg^{2+}) determinations. The concentration of (Mg^{2+}) at equilibrium could be calculated by difference between the amount to total $(Mg^{2+}+Ca^{2+})$ precipitated and the measured (Ca^{2+}) by AA analysis accordingly:

$$(Mg^{2+})_f=(Mg^{2+})_i+[(Ca^{2+})_i-(Ca^{2+})_f] \quad (1)$$

where the subscripts f and i refer to final and initital respectively. To double-check the results, it was also calculated accordingly: $(Mg^{2+})_f=(Mg^{2+})_i+[\Delta+(Ca^{2+})_f-(Ca^{2+})_i]$, where Δ is explained next in calculation.

About 10 mg of the seeds was dissolved by adding drops of 0.5M HCl and dilute to obtain about 1.00 ppm Ca^{2+} and another to obtain about 0.5 ppm $Mg^{2+}$to determine the calcium and magnesium content of the overgrowth by AA's method. This was done by assuming that magnesium content was compositionally homogeneous in the overgrowth coatings. The residual (Na^+)concentration on calcite was also determined by AA's analysis to calculate the residual (Mg^{2+}) and (Ca^{2+}) from the concentration ratios of these major ions to (Na^+) in the original solution.

Calculation

The total CO_2, ΣCO_2, in mole kg^{-1}ASW and total alkalinity, TA, in equivalent kg^{-1}ASW are defined by the equations:

$$\Sigma CO_2=(H_2CO_3^*)+(HCO_3^-)_T+(CO_3^{2-})_T \quad (2)$$

and:

$$TA=(HCO_3^-)_T+2(CO_3^{2-})_T+(OH^-)_T-(H^+)_T \quad (3)$$

because the solution is borate-free artificial seawater. $(H_2CO_3^*)$ is the sum of (H_2CO_3) and CO_2 in solution and the subscript T refer to Total. Carbonate alkalinity, CA, in equivalent kg^{-1} ASW is defined by eqation:

$$CA=TA-(OH^-)_T+(H^+)_T$$
$$=(HCO_3^-)_T+2(CO_3^{2-})_T \quad (4)$$

In terms of ionization fraction (BULTER, 1964, SNOEYINK and JENKINS, 1980; STUMM and MORGAN, 1982):

$$CA=\Sigma CO_2\,(\alpha_1+2\alpha_2) \quad (5)$$

where α_i represents the ionization fraction of ith species of carbonic acid at a certain pH.

Since the precipitaion or dissolution of $CaCO_{3(s)}$ affects both the total carbon dioxide and the carbonate alkalinity, there will be a change in $\Sigma CO_2/CA$ ratio in the solution. The following equation is obtained:

$$\Delta=CA_i\{1/(\alpha_1+2\alpha_2)_i$$
$$-1/(\alpha_1+2\alpha_2)_f]/2[1/(\alpha_1+2\alpha_2)_f]-1\} \quad (6)$$

where Δ is the number of moles of CO_3^{2-} species that is involved in the formation or the dissolution of $CaCO_{3(s)}$ from the initial concentration i to the final concentration f (for details see INGLE, *et al.*, 1973; PLATH and PYTKOWICZ, 1982; RUSHDI, 1993). The concentration of CO_3^{2-} at equilibrium can be calculated by the following equation:

$$(CO_3^{2-})_f=(CA_i+2\Delta)\;[K_2'/(x)+2K_2']_f \quad (7)$$

The apparent solubility products is:

$$^{(Ca)}K_{sp}'=(Ca^{2+})_{T,f}\,(CO_3^{2-})_{T,f} \quad (8)$$

for calcite and:

$$^{(Mg)}K_{sp}'=(Mg^{2+})_{T,f}\,(CO_3^{2-})_{T,f} \quad (9)$$

for magnesite.

3. Result and discussion

The results of the effects of magnesium-to-calcium concentration ratios and the amount of calcite added to ASW at 25℃, upon the apparent solubility products of calcite and magnesite are shown in Table 1. The mean values of apparent solubility product in ASW for degree of supersaturations similar to natural seawater represented by pH≈8.1 versus magnesium concentration are illustrated in Figure (1a) and in ASW of high degree of supersaturation represented by pH≈8.6 in Figure (1b).

Generally, the results in Table1 show that there is an increase in the values of the apparent solubility products with the increase of magnesium concentration in solution as is illustrated in Figure 1a and 1b. This trend of increase with higher magnesium concentration becomes more significant by increasing the degree of supersaturation (Figure 1b). The increase in the degree of supersaturation had no significant change on the apparent solubility products in the absence of magnesium in solution (Figure 1b). This indicates that magnesian ion in solution affects calcite solubility

Table 1. The apparent solubility products of calcite and magnesite as a function of magnesium to-calcium concentration ratios in ASW of two different degree of supersaturations and constant total ionic strength of 0.718 at 25℃.

Exp#	g calcite kg^{-1} ASW	pH_i	pH_f	CA_i meq kg^{-1} ASW(10^{+3})	$(Ca)_f$ mol kg^{-1} ASW(10^{+3})	$(Mg)_f$ mol kg^{-1} ASW(10^{+3})	$^{(Ca)}Ksp'$ mol^2 kg^{-2} ASW(10^{+7})	$^{(Ca)}Ksp'$ mol^2 kg^{-2} ASW(10^{+7})
				$(Mg^{2+}) : (Ca^{2+}) = 0 : 1$				
SC62	0.500	8.087	7.516	2.2935	9.6375	0.00	2.5314	……
SC64	0.492	8.096	7.527	2.2959	9.6372	0.00	2.5968	……
SC66	0.496	8.602	7.611	2.5062	9.4552	0.00	2.8071	……
SC68	0.492	8.585	7.619	2.4959	9.4552	0.00	2.8806	……
SC70	0.997	8.103	7.517	2.2979	9.6334	0.00	2.5314	……
SC72	0.997	8.099	7.513	2.2967	9.6338	0.00	2.5083	……
SC73	0.914	8.120	7.521	2.3024	9.6297	0.00	2.5495	……
SC74	1.388	8.612	7.608	2.5124	9.4370	0.00	2.7760	……
SC75	0.997	8.582	7.616	2.5031	9.4419	0.00	2.7803	……
SC76	5.000	8.080	7.554	2.2917	9.6464	0.00	2.7803	……
SC77	5.004	8.099	7.582	2.2967	9.6466	0.00	2.9676	……
SC78	5.012	8.614	7.630	2.5136	9.4391	0.00	2.9253	……
SC79	5.003	8.613	7.614	2.5130	9.4373	0.00	2.8154	……
				$(Mg^{2+}) : (Ca^{2+}) = 2.9 : 1$				
SC80	0.499	8.096	7.531	2.2799	9.6314	28.8621	2.5314	8.1148
SC81	0.502	8.119	7.565	2.2287	9.7166	28.8621	3.1987	9.7798
SC82	0.499	8.626	7.668	2.5248	9.4970	28.8601	3.5420	10.027
SC83	0.558	8.640	7.644	2.5344	9.4834	28.8610	3.3221	9.4216
SC84	1.008	8.122	7.571	2.2876	9.6311	28.8608	3.2153	8.9040
SC85	1.001	8.157	7.573	2.2985	9.7064	28.8600	3.2390	8.9032
SC86	1.003	8.663	7.642	2.5508	9.4666	28.8620	3.2707	9.2975
SC87	1.002	8.634	7.690	2.5303	9.4094	28.8621	3.6872	10.537
SC88	5.005	8.105	7.595	2.2825	9.7263	28.8603	3.4484	9.4546
SC89	5.001	8.091	7.563	2.2785	9.7244	28.8622	3.1985	8.7702
SC90	5.000	8.628	7.614	2.5262	9.4017	28.8623	3.0790	8.8071
SC91	5.002	8.662	7.595	2.5242	9.5092	28.8622	3.0167	9.3946
				$(Mg^{2+}) : (Ca^{2+}) = 4.99 : 1$				
SC92	0.499	8.152	7.586	2.3662	9.6724	49.0910	4.7224	23.968
SC93	0.500	8.145	7.561	2.3632	9.6700	49.0908	4.4525	22.604
SC94	1.003	8.124	7.539	2.3546	9.6741	49.0914	4.2426	21.529
SC95	0.513	8.619	7.744	2.6578	9.4097	49.0923	5.7292	29.876
SC96	0.501	8.620	7.761	2.6561	9.4051	49.0781	5.8199	24.711
SC97	1.004	8.119	7.586	2.3526	9.6860	49.0923	4.7609	24.130
SC98	1.004	8.620	7.714	2.6553	9.4029	49.0901	5.3289	27.809
SC99	0.968	8.616	7.817	2.6553	9.4277	49.0720	6.8234?	35.563
SC100	1.001	8.612	7.689	2.6518	9.4050	49.0720	5.0424	26.309
SC02	5.002	8.122	7.559	2.3538	9.6854	49.0702	4.4666	22.645
SC03	5.002	8.122	7.589	2.3538	9.6854	49.0924	4.7922	24.290
SC04	4.012	8.619	7.714	2.6550	9.4030	49.0891	5.3291	27.701

products due to its' involvement in the crystal overgrowth. The increase in the surface area of calcite in solutions of lower degree of saturation shows slight effect on the values of apparent solubility products in presence of magnesium in solution. But in a solution of high degree of supersaturation, the surface area of calcite shows a noticeable influence on the apparent solubility products. Generally, the smaller surface area shows a high value of apparent solubility product at a certain magnesium concentration and this values decrease with the increase of calcite surface area in solution of the same magnesium concentration. The high values of apparent solubility products in Figure 1b could be a kinetic control

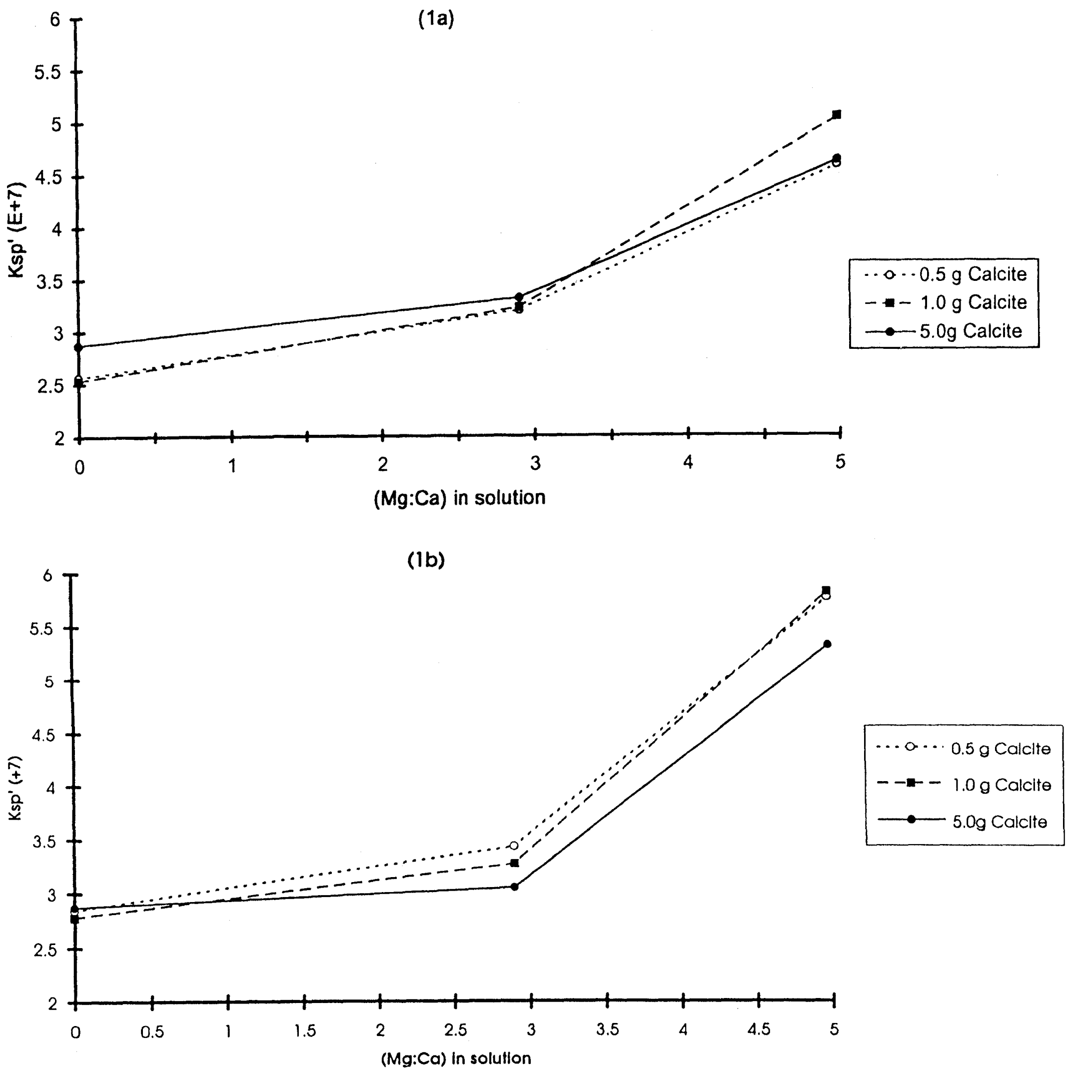

Fig. 1. The apparent solubility products of calcite as a function of Mg-to-Ca concentration ratios and solid to solution ratios in artificial seawater solution at two initial pHs of (la) ≈ 8.1 and (lb) ≈ 8.6.

steady-state equilibrium. The increase in the value of apparent solubility product in magnesium free solutions with the increase of surface area (Figure la) is probably caused by the irregularity of calcite surface structure.

The increase of solubility products with magnesium concnentration in solution may be caused by the effect of magnesium ion-pairs formation and or by the increase of the mole fraction of magnesium on the surface calcite as a result of the overgrowth which enhances its' solubility (CHAVE *et al.*, 1962; MORSE *et al.*, 1979; SCHOONMAKER, 1981; KOCH and DISTECHE, 1984). The experiments indicate that there are two forces enhancing the involvement of magnesium in overgrowth precipitaion: the increase of magnesium concentration in solution and the increase of apparent ionic products of carbonate in solution. Therefore, the increase of magnesium fraction on calcite overgrowth surface is probably more effective upon the solubility product values of calcite than the ion

Table 2. The mole fraction $CaCO_{3(s)}$ in calcite overgrowth coatings as a function of (Mg^{2+}): (Ca^{2+}) concentration ratios in ASW, determined by AA analysis assuming that the calcite overgrowth is compositionally homogenous.

Expt #	$^{x}CaCO_{3(s)}$	$^{x}MgCO_{3(s)}$
$(Mg^{2+}):(Ca^{2+}):2.92:1$		
SC80	0.946	0.054
SC81	0.946	0.054
SC86	0.944	0.056
SC87	0.946	0.054
SC89	0.947	0.053
SC90	0.948	0.052
SC91	0.947	0.053
$(Mg^{2+}):(Ca^{2+}):4.99:1$		
SC92	0.926	0.074
SC93	0.924	0.076
SC95	0.916	0.084
SC96	0.918	0.082
SC97	0.928	0.072
SC98	0.926	0.074
SC100	0.922	0.078
SC02	0.928	0.072
SC03	0.929	0.071

pairing effect, because the activity of magnesian calcite overgrowth is not unity any more. The calcium carbonate fractions, $^{x}CaCO_{3(s)}$, on calcite overgrowth are shown in Table 2 as determined by AA analysis. The results show an increase of $^{x}MgCO_{3(s)}$ on calcite overgrowth coatings with the increase of (Mg^{2+})-to-(Ca^{2+}) concetnration ratios in ASW.

If the activity of calcite in the test solution is assumed to be a unity and do not really affect the solubility of the solid phase and by assuming that the increase of the solubility of calcite in Table 1 is mainly caused by ion-pairs formation, then the free solubility products of calcite $^{(Ca)}K_{sF}$, as well as magnesite, $^{(Mg)}K_{sF}$, in different solutions which are expressed by:

$$^{(Ca)}K_{sF}=(Ca^{2+})_{F,f}\,(CO_3^{2-})_{F,f} \qquad (8)$$

and:

$$^{(Mg)}K_{sF}=(Mg^{2+})_{F,f}\,(CO_3^{2-})_{F,f} \qquad (9)$$

may have the same values or very slight changes with the increase of (Mg^{2+}) in solution because $MgHCO_3^{+}$, $MgCO_3^{0}$, $MgCaCO_3^{2+}$ and $CaCO_3^{0}$ ion-pairs have been taken care of in the process of calculation. The subscripts F and f in equations (8) and (9) are referring to free and final (equilibrium) respectively. The free and ion-pairs are calcuated for only those experiments of lower degree of supersaturation (that is, to avoid the kinetic control conditions) by using the MICROQL program (WESTALL, 1979) as shown by RUSHDI and CHEN, (1995). The values of the free solubility products are listed in Table 3. It is noticed that the value of $^{(Ca)}K_{sF}$ increase by 194%, which is the same magnitude of increment for apparent solubility product of calcite, with the increase of (Mg^{2+}) from 0 to 0.05 mole kg^{-1} ASW. This indicates that the increase of K_{sF} and Ksp' values are probably caused by the increase of magnesian calcite dissolution due to the increase in activity of the solid.

The thermodynamic solubility products of calcite, K_{so}, could be calculated from the relation:

$$^{(Ca)}K_{so}={}^{a}Ca^{2+\,a}CO_3^{2-} \qquad (12)$$

and the following equations are applied:

$$^{(Ca)}K_{so}=(\gamma_{Ca^{2+}})_{T,f}(Ca^{2+})_{T,f}(\gamma_{CO_3^{2-}})_{T,f}(CO_3^{2-})_{T,f} \qquad (13)$$

or:

$$^{(Ca)}K_{so}=(\gamma_{Ca^{2+}})_{F,f}(Ca^{2+})_{F,f}(\gamma_{CO_3^{2-}})_{F,f}(CO_3^{2-})_{F,f} \qquad (14)$$

where(γ_i) and (i) represent the activity coefficient and the concentration of the ith species respectively. The same realtions are appropriate for magnesite.

The free activity coefficient of CO_3^{2-}, $(\gamma_{CO_3^{2-}})_{F,f}$, is calculated from

$$(\gamma_{CO_3^{2-}})_{F,f}=(\gamma_{CO_3^{2-}})_T(CO_3^{2-})_T/(CO_3^{2-})_F$$

The values of $(\gamma_{CO_3^{2-}})_T$ in different(Mg^{2+})-to-(Ca^{2+}) concentration ratios in ASW are listed in Table 4 and $(CO_3^{2-})_F$ as described by RUSHDI and CHEN (1995). The free activity coefficients of magnesium and calcium cations, represented by $(M^{2+})_F$, are estimated from the equation:

$$(\gamma M^{2+})_F=(\gamma\pm MCl_2)_F^{3}/(\gamma\pm KCl)_F \qquad (16)$$

where $(\gamma\pm)_F$ represents the free mean activity coefficients.

The free activity coefficients of KCl, $CaCl_2$, $MgCl_2$ are calculated from the general equation

Table 3. The free solubility products of calcite and magnesite represented by pK_{sF} as a function of (Mg^{2+}):(Ca^{2+}) concentration ratios in ASW.

Expt #	$-\log(Ca^{2+})_{F,f}$	$-\log(CO_3^{2+})_{F,f}$	$p^{(Ca)}K_{sF}$	$p^{(Mg)}K_{sF}$
		(Mg^{2+}):$(Ca^{2+})=0:1$		
SC62	2.380	4.600	6.980	……
SC64	2.378	4.589	6.967	……
SC66	2.397	4.550	6.947	……
SC70	2.378	4.600	6.978	……
SC72	2.371	4.604	6.975	……
SC73	2.378	4.597	6.975	……
SC74	2.380	4.555	6.959	……
SC76	2.378	4.661	6.939	……
SC77	2.371	4.534	6.905	……
SC78	2.390	4.533	6.924	……
SC79	2.387	4.549	6.936	……

Expt #	$-\log(Ca^{2+})_{F,f}$	$-\log(Mg^{2+})_{F,f}$	$-\log(CO_3^{2+})_{F,f}$	$p^{(Ca)}K_{sF}$	$p^{(Mg)}K_{sF}$
		(Mg^{2+}) : $(Ca^{2+})=2.961:1$			
SC80	2.339	1.819	4.547	6.885	6.365
SC81	2.365	1.819	4.514	6.878	6.333
SC84	2.339	1.819	4.509	6.848	6.329
SC85	2.365	1.819	4.508	6.873	6.328
SC88	2.353	1.819	4.485	6.875	6.304
SC89	2.335	1.819	4.515	6.875	6.335
SC90	2.379	1.820	4.519	6.898	6.339
SC91	2.376	1.820	4.537	6.913	6.357
		(Mg^{2+}) : $(Ca^{2+})=4.99:1$			
SC92	2.312	1.566	4.345	6.657	5.911
SC93	2.311	1.566	4.366	6.679	5.932
SC94	2.311	1.566	4.385	6.697	5.951
SC97	2.311	1.566	4.342	6.654	5.908
SC02	2.311	1.566	4.366	6.677	5.932
SC03	2.312	1.566	4.334	6.651	5.906

Table 4. Total activity coefficients of bicarbonate and carbonate ions in the test solutions of various (Mg^{2+}) : (Ca^{2+}) concentration ratios at 25℃ and $I_T=0.718$(as shown by RUSHDI and CHEN , 1995).

(Mg^{2+}):(Ca^{2+})	$(\gamma HCO_3^-)_T$	$(\gamma CO_3^{2-})_T$
0:0	0.574	0.117
0:1	0.553	0.065
1:1	0.539	0.060
3:1	0.529	0.054
5:1	0.505	0.033

of the activity of the electrolyte MCl_q which could be expressed in two equivalent ways:

$$^{a}MCl_q=(\gamma_M)_T(M)_T[(\gamma_{Cl})_T(Cl)_T]^q \quad (17)$$

and:

$$^{a}MCl_q=(\gamma_M)_F(M)_F[(\gamma_{Cl})_F(Cl)_F]^q \quad (18)$$

by combining equations (17) and (18) they yield:

$$(\gamma\pm MCl_q)_F=(\gamma\pm MCl_2)_T[(M)_T(Cl)_T^q/(M)_F(Cl)_F^q]^{(1/(q+1))} \quad (19)$$

To apply equation (19), first the effective ionic strength, I_e, for each solution is calculated from:

$$I_e=0.5[\Sigma(F)Z_{F,e}^2+\Sigma(ip)Z_{ip}^2] \quad (20)$$

where the concentration of free ion, (F), and the ion-pair, (ip), are calculated by MICROQL program (WESTALL, 1979). Secondly, different effectivie ionic strength are used to calculate the equivalent total ionic strength of KCl, $MgCl_2$ and $CaCl_2$. This is done following the same iterative procedure which was described by JOHNSON (1979 p88) and JOHNSON and

Table 5. The constants of the equation (22) used to calculate total mean activity coefficients of electrolyte of interest (PYTKOEICA, *et al.*, 1977).

Electrolyte	A	B	C	D	E
KCl	−0.5108	1.307	0	0	0.002075
$MgCl_2$	−1.0216	1.800	−0.03365	0.1156	−0.04101
$CaCl_2$	−1.0216	1.501	0.07898	−0.01545	0

Table 6. The estimated mean total and free activity coefficients of KCl, $MgCl_2$ and $CaCl_2$, and the free activity coefficients of Mg^{2+}, Ca^{2+} and CO_3^{2-} as a function of $(Mg^{2+}):(Ca^{2+})$ concentration ratios in ASW.

$(Mg^{2+}):(Ca^{2+})$ Ratio	I_e	KCl		$MgCl_2$		$CaCl_2$		$(\gamma Mg)_F$	$(\gamma Ca)_F$	$(\gamma CO_3)_F$
		$(\gamma\pm)_T$	$(\gamma\pm)_F$	$(\gamma\pm)_T$	$(\gamma\pm)_F$	$(\gamma\pm)_T$	$(\gamma\pm)_F$			
0:1	0.610	0.619	0.803	0	0	0.4506	0.6959	0	0.4197	0.247
3:1	0.596	0.621	0.800	0.4749	0.698	0.4512	0.6922	0.4253	0.4146	0.229
5:1	0.583	0.623	0.799	0.4753	0.695	0.4520	0.6926	0.4158	0.4158	0.217

PYTKOWICZ, (1978) used to estimate the stability constants K^*_{MCl}. Then the effective ionic strengths is plotted versus total ionic strength of KCl, $MgCl_2$ and $CaCl_2$ and least square method is used to fit the data. The following equation is obtained to calculate the equivalent total ionic strength, I_T, of the electrolyte salts:

$$I_{T,MCl_q} = (I_{e,MCl_q} - \beta_0)/\beta_1 \qquad (21)$$

where constants $\beta_0 = 0.083$; 0.107 and 0.1099 and $\beta_1 = 0.6737$, 0.5166 and 0.475 for KCl, $MgCl_2$ and $CaCl_2$ respectively. The total mean activity coefficinets of KCl, $MgCl_2$ and $CaCl_2$ are calculated from Culberson equation (PYTKOWICZ, *et al.*, 1977) after converting ionic strength to molality scale:

$$\log(\gamma \pm_{MClq}) = AI_T^{0.5}/(1+BI_T^{0.5}) + CI_T + DI_T^{1.5} + EI_T^2 \qquad (22)$$

The constants of this equations are listed in Table 5.

At this point, equation (19) could be used to calculate the single free activity coefficient of the cation (M^{2+}). The values of the estimated mean activity coefficients of KCl, $MgCl_2$, $CaCl_2$ and the free single activity coefficients of Ca^{2+} and Mg^{2+} of different (Mg^{2+})-to-(Ca^{2+}) concentration ratios in ASW in molal scale are listed in Table 6.

The thermodynamic solubility products of calcite and magnesite were calculated according to equations(13) and (14), after converting the concentration of the ions into molal scale in which the activity of the solid phase was assumed to have a value of unity. Their values are listed in Table 7, which show an increase of the thermodynamic constants values with $(Mg^{2+})$to-(Ca^{2+})concentration ratios in ASW. This indicates that the activity of the solid phase is more than one.

Thus, by assuming that the activity of the solid is about unity for both ${}^{(Ca)}K_{so}$ at zero (Mg^{2+}) and ${}^{(Mg)}K_{so} = 1.07 \times 10^{-8}$ $moles^2 kg^{-2} H_2O$ (GARRELS and CHRIST, 1965; ROBBIE and WALDBAUM, 1968), then the activity of the solid phase as a result of the impurities are calculated from:

$$^{a}CaCO_{3(s)} = {}^{(Ca)}K_{so(Mg:Ca)}/{}^{(Ca)}K_{so(Mg=0)} \qquad (23)$$

$$^{a}MgCO_{3(s)} = {}^{(Mg)}K_{so(Mg:Ca)}/{}^{(Mg)}K_{so(Ca=0)} \qquad (24)$$

where the subscripts (Mg=0), (Ca=0) and (Mg : Ca) are respectively the K_{so} value when $(Mg^{2+})=0$, $(Ca^{2+})=0$ and $(Mg^{2+}):(Ca^{2+})$ concentration ratios in solution. The activities of the solids phases are also shown in Table 7. It is shown that the activity of magnesite is higher than calcite, which indicates a type of a nonideal solid solution is formed.

The activity coefficients of calcite, $\lambda CaCO_{3(s)}$, and magnesite, $\lambda CaCO_{3(s)}$, are calculated from the equations:

$$\lambda CaCO_{3(s)} = {}^{a}CaCO_{3(s)}/{}^{x}CaCO_{3(s)} \qquad (25)$$

and:

$$\lambda MgCO_{3(s)} = {}^{a}MgCO_{3(s)}/{}^{x}MgCO_{3(s)} \qquad (26)$$

Table 7. Estimated Kso of calcite and magnesite, assuming that the activity of the solid was unity. The values in the last two columns are the predicted values of the solid activity precipitated from different $(Mg^{2+}):(Ca^{2+})$concentration ratios in ASW.

Expt #	$^{(Ca)}K_{so}$ $(mole/kgH_2O)^2$ (10^{+9})	$^{(Mg)}K_{so}$ $(mole/kgH_2O)^2$ (10^{+8})	$^aCaCo_{3(s)}$	$^aMgCo_{3(s)}$
		$(Mg^{2+}):(Ca^{2+})=0:1$		
SC62	3.1392	–	1	–
SC64	3.2167	–	1	–
SC70	3.1392	–	1	–
SC72	3.1600	–	1	–
SC73	3.1600	–	1	–
		$(Mg^{2+}):(Ca^{2+})=2.96:1$		
SC80	3.3078	1.1225	1.0657	1.0491
SC81	3.3637	1.1083	1.0624	1.1293
SC85	3.4013	1.2200	1.0753	1.1402
SC89	3.3876	1.2936	1.0710	1.1249
SC90	3.2116	1.1906	1.0154	1.1127
SC91	3.1041	1.1428	1.9814	1.0680
		$(Mg^{2+}):(Ca^{2+})=4.99:1$		
SC92	3.7221	2.0744	1.1767	1.9387
SC93	3.5390	1.9765	1.1189	1.8472
SC94	3.3971	1.8919	1.0740	1.7681
SC97	3.7521	2.0879	1.1863	1.9513
SC02	3.5529	1.9765	1.1233	1.8472
SC03	3.7721	2.0994	1.1926	1.9621
		$(Mg^{2+}):(Ca^{2+})=1:0$		
1*	–	1.07	–	1

* = the value is calculated from $^{(Mg)}K_{so}=2.82\,^{(Ca)}K_{so}$ according to ROBBIE and WALDBAUM (1968) and GARRELS and CHRIST (1965).

The calculated values of $\lambda_{CaCO_{3(s)}}$ and $\lambda_{MgCO_{3(s)}}$ as well as the mole fraction of magnesium in solution at equilibrium, y_f, and the mole fraction of $CaCO_{3(s)}$, in calcite overgrowth are listed in Table 8. The large increase of $\lambda_{MgCO_{3(s)}}$ in the solid could be attributed to the effect of magnesium ion on the crystal lattice of calcite. The incorporation of smaller magnesium ion in the crystal lattice causes a distortion of the lattice which leads to a nonideal solid solution formation (RUSHDI, 1992).

The following general equilibrium reaction equation for magnesian calcite is usually used:

$$x_eMg^{2+}+(1-x_e)Ca^{2+}+CO_3^{2-}\rightleftarrows Mg_{x_e}Ca_{(1-x_e)}CO_3 \quad (27)$$

and it's thermodynamic solubility product is expressed as:

$$^{(Mg-cal)}Kso = (^aMg^{2+})^{xe}(^aCa^{2+})^{(1-x_e)}(^aCO_3^{2-})/(^aMgCO_3)^{x_e}(^aMgCO_3)^{(1-x)_e} \quad (28)$$

Another type of thermodynamic solubility product equation, used in literature is defined by the ion activity product (IAP) equation:

$$^{(Mg-cal)}Kso = (IAP) = (^aMg^{2+})^{x_e}(^aCa^{2+})^{(1-x_e)}(^aCO_3^{2-}) \quad (29)$$

which is similar to equation (28) except that the activity of solid magnesian calcite is assumed to be one. The two types of the above equations are used to estimate the values of thermodynamic solubility products of magnesian calcite as a function of (Mg^{2+})-to-(Ca^{2+}) concentration ratios in ASW. The results are shown in Table 9 and Figure 2. The results show slight changes in $^{(Mg-cal)}K_{so}$, as a function of (Mg^{2+})-to-(Ca^{2+}) concentration ratios in solution by using equation (28), whereas equation (29) shows a noticeable increase of (IAP) with respect to Mg^{2+} in solution.

Table 8. The activity coefficients of calcite and magnetite, estimated from and $^{x}CaCO_{3(s)}$ as a function of $(Mg^{2+}):(Ca^{2+})$ concentration ratios in ASW.

Expt #	y_f	$^{x}CaCO_{3(s)}$	$^{x}MgCO_{3(s)}$	$\lambda\, CaCO_{3(s)}$	$\lambda\, MgCO_{3(s)}$
		$(Mg^{2+}):(Ca^{2+})=2.96:1$			
SC80	0.750	0.947	0.053	1.1253	19.7943
SC81	0.750	0.946	0.054	1.1230	20.9130
SC85	0.750	0.948	0.052	1.1343	21.9927
SC89	0.750	0.949	0.051	1.1286	22.0569
SC90	0.749	0.949	0.051	1.0700	21.8176
SC91	0.749	0.951	0.049	1.0320	21.7959
		$(Mg^{2+}):(Ca^{2+})=4.99:1$			
SC92	0.835	0.924	0.076	1.2735	25.5092
SC93	0.835	0.925	0.075	1.2096	24.6293
SC94	0.835	0.926	0.074	1.1598	23.8932
SC97	0.835	0.926	0.074	1.2811	26.3689
SC02	0.835	0.929	0.071	1.2091	26.0169
SC03	0.835	0.928	0.072	1.2851	27.2514

Table 9. The estimated thermodynamic solubility products of magnesian calcite as a function of $(Mg^{2+}):(Ca^{2+})$ concentration ratios in ASW calculated by equations (28) and (29).

Expt #	$(Mg^{2+}):(Ca^{2+})$ Ration	Equation (28) (E+9)	Equation (29) (E+9)
SC62	0:0.09	3.139	3.139
SC81	2.96:1	3.310	3.525
SC85	〃	3.378	3.600
SC89	〃	3.551	3.813
SC??	〃	3.355	3.421
SC92	4.99:1	3.418	4.177
SC93	〃	3.485	4.049
SC94	〃	3.471	3.868
SC97	〃	3.466	4.266
SC02	〃	3.453	4.019

Finally, in ASW of magnesium-to-calcium concentration ratio of 5, the apparent solubility product, Ksp′, is in agreement with Ksp′ found by KOCH and DISTECHE (1984). They related that to the surface overgrowth of 2 to 3 mole% magnesian carbonate. But according to this study it may be related that to surface overgrowth of about 7.4 mole% $MgCO_3$. MUCCI *et al.*, (1985) using Scanning Auger Microanalysis showed that the (Mg^{2+})-to-(Ca^{2+}) concentration on $CaCO_{3(s)}$ surface increases with the increase of (Mg^{2+})-to-(Ca^{2+}) concentration in solution. They strongly suggest that magnesian calcite overgrowth is in exchange equilibrium with the solution from which it precipitated and that is representative of the solubility controlling phase. Our results suggest that there may be two types of controlling factors: the thermodynamic and the kinetic controls (PYTKOWICZ and COLE 1979). The thermodynamic control is effective at low degree of saturation, where by the increase of surface area showed a very slight changes and the kinetic control is effective at high degree of supersaturation where the increase of surface area plays a significant role on the steady-state condition.

4. Conclusion

Although, the thermodynamic calculation of

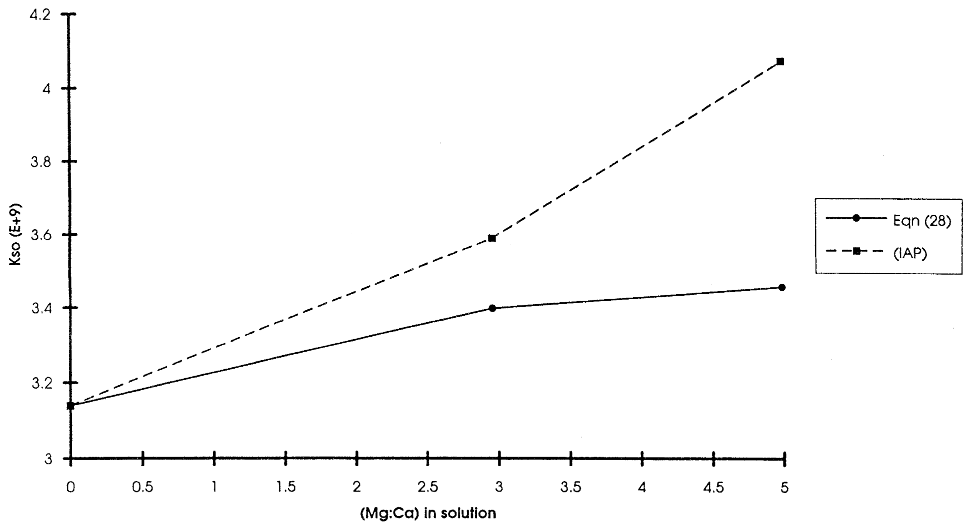

Fig. 2. Thermodynamic solubility products of magnesian calcite as a function of Mg-to-Ca concentration ratios in artificial seawater solution represented by equations (28) and (29).

calcite solubility in solution indicates that the activity of the solid increases due to the involvement of magnesium ion in the overgrowth process of calcite, there are other factors that may affect the solubility of calcite. Such examples are the irregularity of surface structure, shape, morphology and mineralogy of crystals. The increase of the values of thermodynamic solubility product of calcite may also indicate that there are more than one thermodynamic states, depending on the chemical and physical condition of the reaction.

One can conclude that in natural environment where the degree of supersaturation is close to saturation level, the inorganic precipitation of magnesian calcite tends to approach thermodynamic equilibrium. But when the degree of saturation is high enough to enhance the formation of high magnesian calcite overgrowth or biogenic precipitaion of high magnesian calcite, the kinetic control is favored over thermodynamic equilibrium. The kinetically controlled steady-state may approach the thermodynamic equilibrium if some process becomes effective that causes changes in the phases of the system and if enough time is given. One of these processes is the increase of solid-to-solution ratios.

Another conclusion is that the apparent solubility product values measured in laboratory experiments could be applied to environments of low degree of saturation as well as to natural system where there is a large solid-surface in contact with the solution such as in sediments or places where there are suspended particles. At high degree of saturation and in environments where there are small amount of particles, such as in open ocean surface water, the apparent solubility products measured in laboratory are still questionable.

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Impact of aquatic pollution and its effect on fisheries in Bangladesh

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Abstract: Bangladesh is uniquely endowed with vast water resources. The near-shore sea, estuaries, mangroves, rivers, lakes, and pond all taken together, offer tremendous opportunities for farming of fish and shell fishes. The effect of heavy metal on the aquatic environments was reviewed, localized anthropogenic sources of heavy metals in Bangladesh show evidently the future deleterious effects on the aquaculture environment that eventually cause the decline of fish production. Degradation of the environment through natural and anthropogenic interventions has been identified as the primary causes for the decline in open water capture fishery production. Due to rapid industrial development of the country, industrial pollution may, in time, become a threat to the aquatic environment. No systematic studies have been done so far on the impact of industrial pollution on aquatic life. Industrial effluents specially the discharge of fertilizer, petrochemical, tanneries, pulp and paper mills, distilleries and thermal power plants might have adverse effects on the aquatic life. It is also anticipated that indiscriminate use of pesticides for crop production may partially responsible for hydrological degradation of rivers leading to the decline of fish production in open water of Bangladesh. In recent years, the impact of aquatic pollution on human and animal life has become a matter of special concern of ecologists in general, and aquaculturists in particular.

1. Introduction

Bangladesh is located in South Asia between lat 20° 34″ and 26° 38″ N and long 88° 01″ and 92° 41″ E(Fig. 1) and is surrounded by the Bay of Bengal, the Gangetic plains fo India and the forest of Myanmar. It is primarily a low lying plain of about 148,000 km^2 criss-crossed by innumerable water courses including the mighty rivers Padma, Jamuna, Meghna and Karnaphuli. Other important rivers include the Teesta, old Brahmaputra, Karatoa, Surma, Shitalakhy, etc. During peak periods, these rivers and their tributaries discharge a total of about 5 million cubic feet per second into the Bay of Bengal. Water resources are one of the most critical and valuable components of the natural resources of Bangladesh. Its rich soils and humid climate also have brought about some of the most fertile agricultural land in the world (JICA, 1997). Bangladesh has a tropical monsoon climate. The country has mainly four seasons : winter (December-February), summer (March-May), monsoon (June-September), and autumn (October-November).

Aquaculture, as a major component of agriculture in Bangladesh, is practiced either as a primary or secondary source of income. The contribution of agriculture to the country's gross domestic product is 45%, of which 6% comes from fisheries. In the agriculture-based economy, fish and fisheries play an important role in nutrition, income, employment, poverty alleviation and foreign exchange earnings, contributing 73% to national animal protein intake and 10% to export earnings, in addition to providing full-time employment to 1.4 million people and part-time employment to another 11 million (MAZID and ALAM, 1995). An estimated 73% of rural households are involved in rural fishing.

The production of fish in 1993-94 has been

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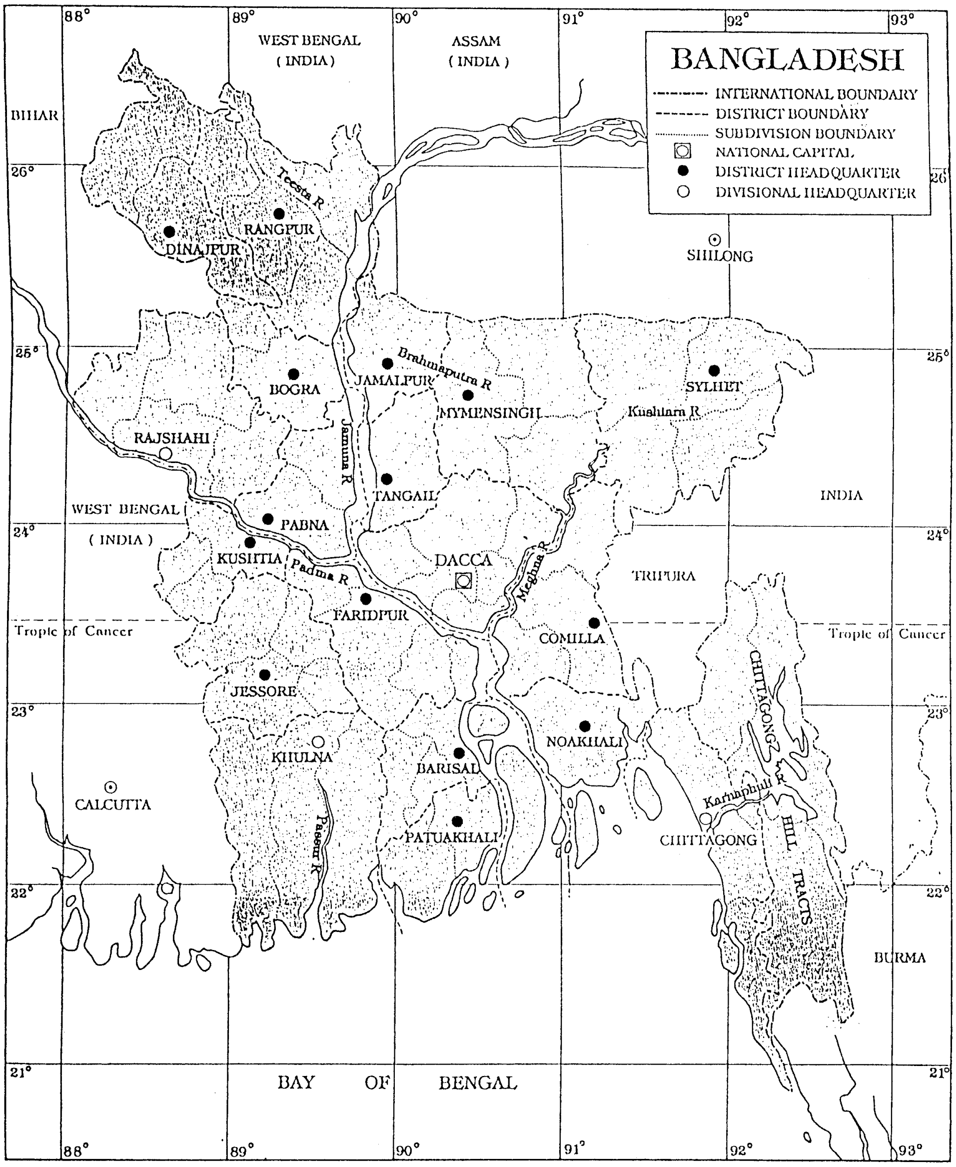

Fig. 1. Map of Bangladesh.

estimated to have been about 1.08 million metric tons. Of this total, inland open water fisheries contribute 51%, inland fresh and brackish water aquaculture 25%, and marine capture fisheries 24%. Current annual consumption fish per caput is about 25.0 g up from 20.5 g in 1989–90. However, to achieve the recommended consumption rate 38.0g $caput^{-1}$ day^{-1}, the country needs to produce about 1.9 million metric tons of fish. Vast potential water resources exist to achieve this production through sustainable development of aquaculture and resource management. The role of fisheries in nutrition and the economy of Bangladesh is shown in Table 1.

1.1. Inland aquatic environment In Bangladesh

Bangladesh has altogether 230 rivers, big and small. Of these, 54 are shared with the upper

Table 1. The role of fisheries in nutrition and economy in Bangladesh.

Fisheries contribution (1993–94)	: 4.0% of GDP 10.0% of export earnings (Tk.13,000 million = US $ 325 million in 94–95) 6.0% of total protein intake 73.0% of animal protein intake
Employment	: 7.0% of total employment
Population engaged in fisheries activities	: Full time 1.4 million : Part time 11.0 million
Recommended daily per caput fish intake	: 38.0 g
Average daily per caput fish intake	: 25.0 g
Average yearly per caput intake	: 9.13 kg
Recommended per caput protein intake	: 45.0 g
Recommended per caput animal protein intake	: 15.0 g
Average per caput animal protein intake	: 11.0 g
Average per caput fish protein intake	: 7.56 g

riparian country, India. These rivers have extensive flood plains i.e., low-lying land along both banks of the river courses. The flood plains remain submerged for 4 to 5 months during the monsoon season. Many of the rivers in the south western region of the country had, in the process of changing courses, left behind ox bow bends which became disconnected from the main rivers thereby turning the bends into isolated reservoirs known as oxbow lakes or locally termed *baors*. An artificial large reservoir of economic importance is Kaptai Lake, the largest man-made freshwater reservoir in Bangladesh as well as in Southeast Asia (FERNANDO, 1980). Kaptai Lake was impounded in 1961 by damming the Karnaphuli River near Kaptai primarily for hydroelectric power generation, but it also paved the way for substantial contributions to the national economy through freshwater fish production, navigation, irrigation and flood control. It has an average area of 68,800 hectare with an average water reserve of 5.2×10^9 m^3. In addition, man made ponds are also scattered all over the country.

The waters are fresh in nature in the inland waters except in the southern region, where the sea influences the rivers. There are estuaries in the southern region with a variable range of salinity. Tidally submersible lands in the south are also used for saltwater shrimp aquaculture. From the fish habitat point of view, the inland water areas can be divided into two broad categories : (a) open-water habitats and (b) closed-water habitats. Inland open-water habitats are rivers (including estuaries), canals, flood plains and *beels* (deep depressions). All of these habitats become components of a single, integrated fishery-production system during the monsoon season. The open water is either flowing (lotic) or standing (lentic). In the rivers and flood plains of Bangladesh, both lotic and lentic conditions are interconnected.

The patterns of movement and migration of riverine fishes and prawns is controlled by the seasonal flooding in the monsoon season. Fish movement and migration in the rivers are upstream or downstream during the greater part of the year and laterally out onto the inundated flood plains during the flood season. The inundated flood plains provide a wide range of habitats for fish reproduction, early development, and growth (DOF, 1986). The flood plains enormously enhance fish productivity in the riverine systems and the *beels*. They also provide habitats for breeding of fish normally resident in stagnant water bodies as well as feeding grounds for their offspring after birth. The estuarine environment, with varying degrees of salinity, is another component of the open inland water fish production system.

1.2. Commercially important fishes and shrimps in Bangladesh

A total of 256 species of fishes have so far

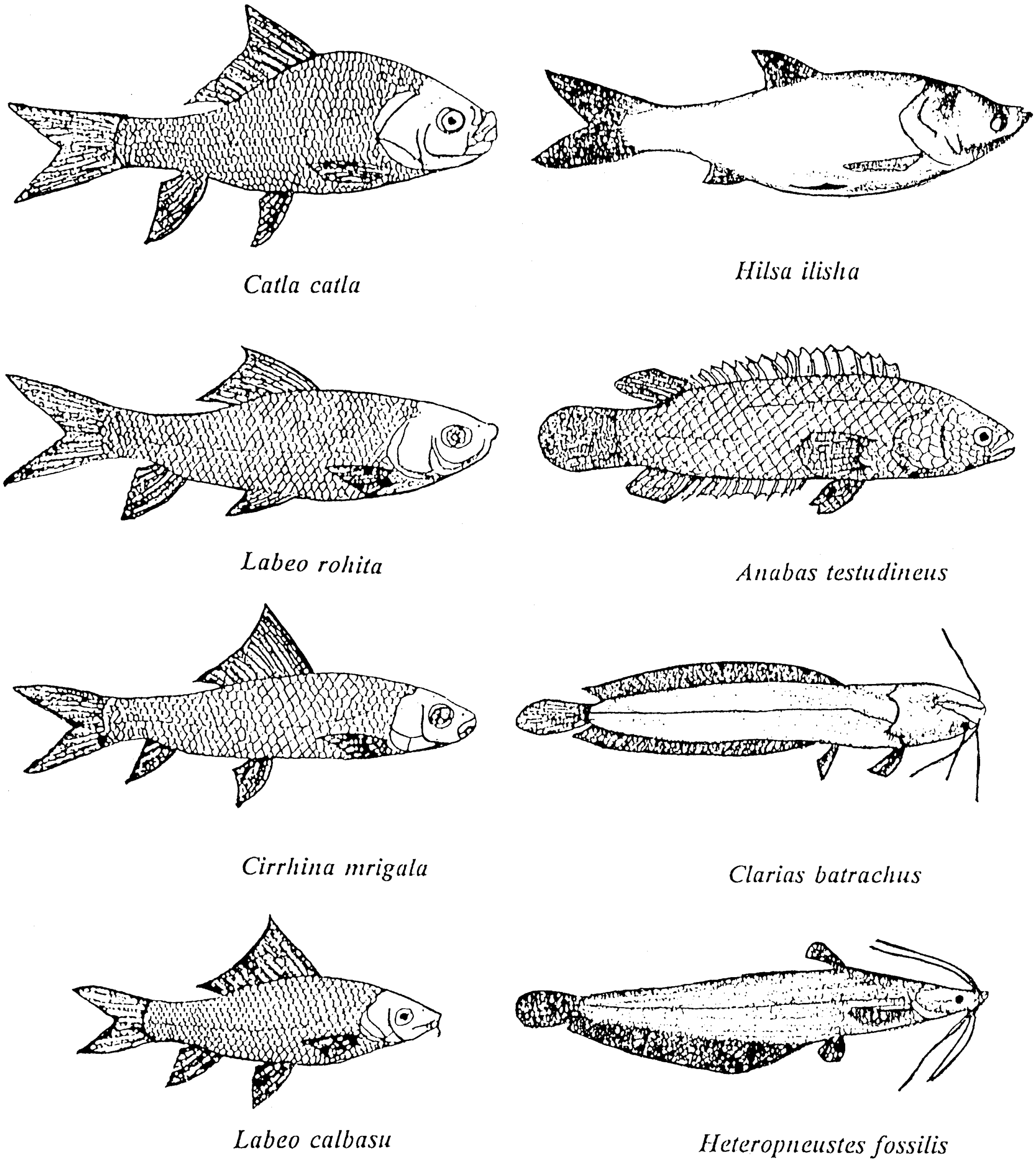

Fig. 2. Commercially important freshwater fishes of Bangladesh.

been recorded from freshwaters in Bangladesh (RAHMAN, 1989). However, it is estimated that about 200 species are truly freshwater culturable forms and the rest are estuarine and marine forms that enter rivers and other freshwater areas during certain periods of their lives. Out of the 200 freshwater species, about 69 species belonging to 23 different families are commercially important. Most of those are carps and catfishes. Some commercially important fresh water fishes and shrimps are shown in Table 2 and Fig. 2. However, at present only major carps, such as *Catla catla*, *Labeo rohita*, *Cirrhinus mrigala* and *Labeo calbasu*, are commonly cultured in a polyculture system in ponds and tanks. Hilsa (*Hilsa ilisa*, family clupeidae and English name shad) is one of the most commercially important species and the largest single fishery in Bangladesh, constituting about 30 to 40% of

Table 2. Commercially important freshwater fishes of Bangladesh.

Family	Fish species	English name	Popular name
Clupeidae	*Hilsa ilisha*	Shad	Ilish
Cyprinidae	*Labeo rohita*	Rohu	Rui
	Catla catla	Catla	Catla
	Cirrhinus mrigala	Mrigala	Mrigal
	Labeo calbasu	Kalbasu	Kalbaus
Cobitidae	*Botia daris*	Loach	
Notopteridae	*Notopterus chitala*	Feather back	Chital
Bagridae	*Mystus aor*	Catfish	Aair
	M. tengra	Catfish	
Siluridae	*Ompok bimaculatus*	Butter catfish	Pabda
	Ompok pabda	Butter catfish	
	Wallago attu	Freshwater shark	Boal
Schilbeidae	*Alia coila*		*Kajoli
Pangastidae	*Panagasius pangasius*	Pungus catfish	Pangus
Claridae	*Clarius batrachus*	Asian catfish	Magur
Heteropneustidae	*Hetropneustes fossilis*		*Shingee
Nandiadae	*Nandus nandus*		*Bheda
Anabentidae	*Anabas testudineas*		*Koi
Channidae	*Channa marulius*	Gaint snakehead	Gagor
	C. punstatus	Green snakehead	Lata
	C. striatus	Striped snakehead	Shoal
Mastacembelidae	*Macrognathus aculeatus*	Spring eel	Tara baim
	Mastacembelus armatus		*Baim
	M. puncalus		*Guicha
Penacidae	*Penaeus monodon*	Gaint tiger shrimp	Bagda
	P. indicus	White shrimp	
	P. japonicus		

* Bengali popular name

the total fish catch of the country.

Hilsa, is also the most popular fish in the country.

Shrimps are a major foreign exchange earner for most Asian countries including Bangladesh. Export of shrimps stands next in earnings to garments, jute and jute goods, and leather ; it contributed to 6.50 % of the total export earnings in 1991 to 1992. The major exports market for Bangladesh frozen shrimps are the U.S.A, Japan and Germany. Twenty five shrimp species have been identified in Bangladesh, of which 8 commercial species (Fig. 3) are available in the trawl fishery. Although shrimps represent only 2.5% of the total marine catch, it is considered an important money making component of the catch.

During 1994–95, export earnings from fish and fishery products increased considerably to Tk. 13,000 millions (US $ 325 m ; Tk.40 = US $ 1) in foreign exchange, of which the export of shrimp alone contributed to Tk.10,400 millions (US $ 260m) (DOF, 1994). Of the country's total shrimp catch of 101,025 tons, 53,520 tons were from the water bodies and about 23,530 tons were from coastal shrimp farms (HUSSAIN and UDDIN, 1995).

1.3. Types of Fisheries in Bangladesh

Bangladesh is bestowed with vast and highly diverse aquatic resources, which can be categorized as (a) inland capture fisheries, (b) freshwater and brackish water aquaculture, and (c) marine fisheries. The inland fisheries category is again subdivided into the open water capture fishery and the closed water culture fishery. The open water capture fishery is constituted by rivers, estuaries, canals, flood plains, reservoirs and inundated paddy fields and ponds, covering an area of 4.3 million

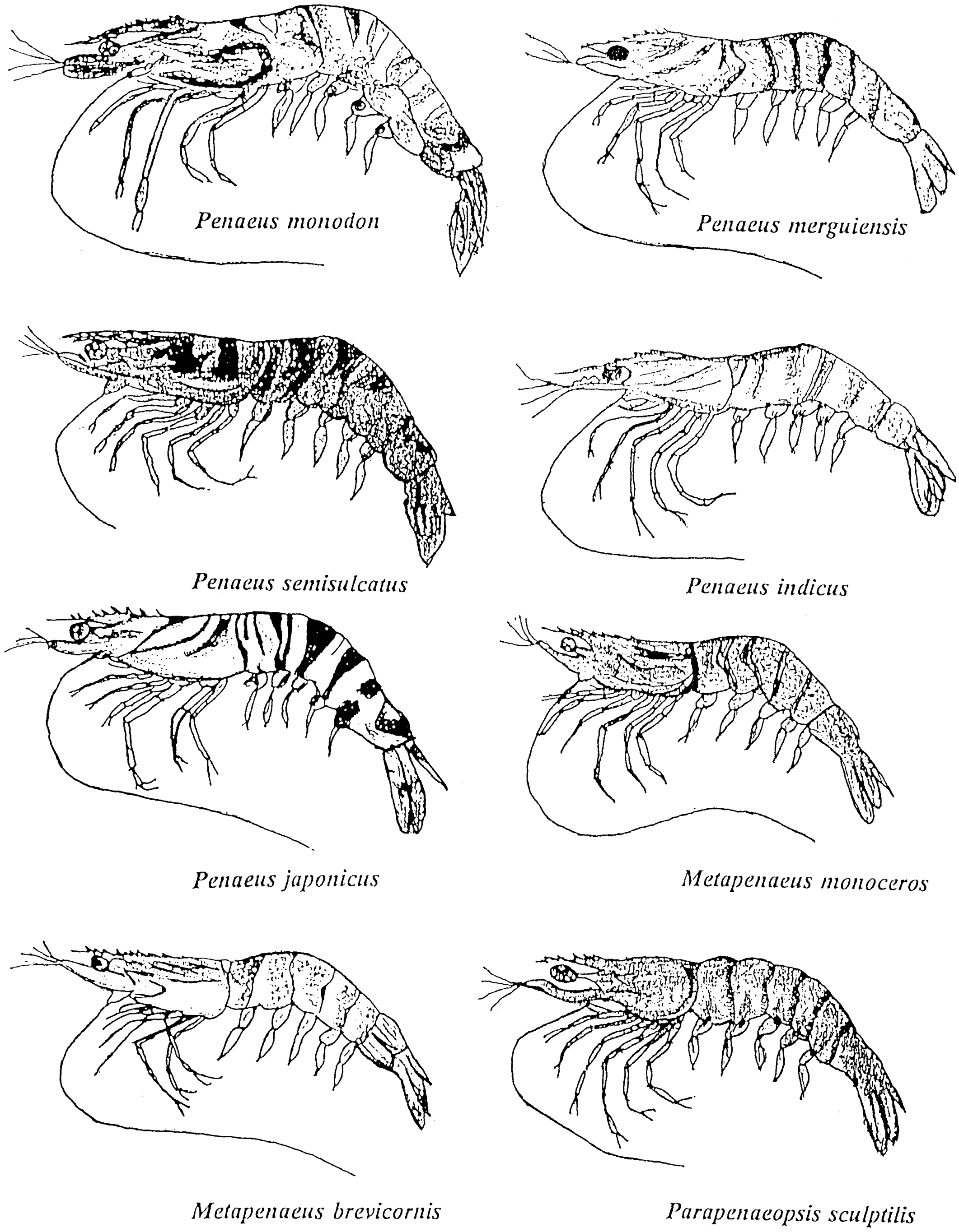

Fig. 3. Commercially important marine shrimps of Bangladesh.

Table 3. Estimated area of different fisheries resources and their production in 1993-94.

Source	Water area (ha)	Production (tons)	% contribution to total production
A. Inland fisheries			
a. Inland open water capture			
Rivers & esuaries	1,031,563	137,000	12.6
Flood plains	2,832,079	353,000	32.5
Beels & Haors	114,161	57,000	5.2
Reservoir	68,800	5,150	0.5
Sub-Total	4,046,603	552,150	50.8
b. Inland closed water culture	146,890	231,000	21.2
Ponds	5,488	2,000	0.2
Oxbow lakes (Baors)			
Brackish water farms	125,000	42,000	3.9
Sub-Total	277,378	275,000	25.3
Inland Total(a+b)	4,323,981	827,150	76.1
B. Marine fisheries			
Industrial		15,000	1.4
Artisanal		245,000	22.5
Marine Total		260,000	23.9
GRAND TOTAL(A+B)		1,087,150	100.00

hectares. The rivers and estuaries contribute the major component of open water capture fishery production, about 0.13 million metric tons and 12.6% of the total national production during 1993-94. The major group in riverine fisheries is Hilsa and the second most important group is the Indian major carps. The rest of the catch consists of other medium and minor carps, catfishes, snakeheads and shrimp. Rivers are also the most important source of major carp seed for closed water culture fisheries. The culture fisheries include 150 thousand hectares of freshwater ponds, 5 thousand hectares of oxbow lakes and about 125 thousand hectares of coastal shrimp farms. The country has a 480 km coastline of along the Bay of Bengal with an area of 64,000 km^2. These vast and varied aquatic resources support artisanal and commercial fisheries as well as offer opportunities for aquaculture development. The inland, coastal and marine water resources along with their productions are shown in Table 3.

1.4. Aquaculture

Throughout the world, aquaculture is being looked upon as a panacea for meeting the increasing demand for fish, as catches from open waters are declining due to overexploitation and degradation of fish habit ats ; in these respects, Bangladesh is no different. Inland water bodies of Bangladesh are highly productive and give about 76% of the total fish production. The fish production from inland open water capture fisheries is declining continuously due to massive construction of flood control structures, overexploitation, extraction of water for irrigation, intensive agriculture and industrial development, erosion and siltation, reclamation of land for human settlement, pollution, destruction of mangrove forests, etc. At the same time demand for fish has increased because of the rapidly expanding population. Over the last fifteen years, the fish consumption per caput in Bangladesh has declined by about 30%. Pollution from industrial and municipal wastes have had devastating effects on fish stocks of the country. Unless appropriate action is taken to reverse the present declining trend of open water capture fisheries, the overall situation will not improve even if it is possible to make substantial headway in culture fisheries.

Table 4. Major pollutants of the environment in Bangladesh.

1. Industrial Pollution
   - A. Paper & Pulp Industries
   - B. Fertilizer industries
   - C. Leather industries
   - D. Textile industries
   - E. Sugar industries
2. Thermal pollution
3. Agro-chemical pollution
4. Municipal wastes
5. Oil pollution
6. Solids and sludges
7. Microbial contamination

Degradation of the environment through natural and anthropogenic interventions has been identified as the primary causes for the decline in open water capture fishery production. Due to rapid industrial development of the country, industrial pollution may, in time, become a threat to the aquatic environment. No systematic studies have been done so far on the impact of industrial pollution on aquatic life. In recent years, the impact of aquatic pollution on human and animal life has become a matter of special concern of ecologists in general, and aquaculturists in particular. Major pollutants of Bangladesh are shown in Table 4.

The present paper aims to draw attention to some of the environmental management problems with respect to fishery resources.

2. Major pollutants and their sources

2.1. Industrial pollution

Bangladesh now contains 30-thousand industrial units, of which about 24 thousand are small and cottage industries. The industrial establishments are mostly located on the shores of rivers and other waterways. Almost all the industries in Bangladesh lack waste treatment facilities. They do not use any treatment for effluents. Pollution in these areas can be highly concentrated. They discharge their treatment liquid and solid wastes directly or indirectly into the water bodies, which finally find their way into the Bay of Bengal. This problem also increases the concentrations of heavy metals in aquatic ecosystems. Heavy metals produce undesirable effects on animal life, even if they are present it extremely minute quantities.

A national survey by the Department of Environment identified 903 units as major polluters under 13 categories (Table 5). There are more 600 chemicals that are classified as hazardous and toxic. The chief contaminants are ammonia; chromium and other heavy metals from fertilizer and tanneries; mercury from paper and pulp chloralkali units; and phenols from pulp and paper, refinery, pharmaceutical and paint industries. These pollutants affect

Table 5. Major industries and their probable toxic pollutants in Bangladesh.

Industry	Number	Water borne effluents
Textile Industries	298	Alkali, Chlorine, Chromium
Tanneries	176	Chromium, Sulphates, SS, BOD
Pharmaceutical Industries	166	Mineral & organic acids, Phenol
Jute Industries	92	SS
Iron & Steel Mills	57	Acids, Cyanides, SS
Rubber & Plastic Industries	34	Solvents, Oils, SS, BOD
Pesticide Industries	25	Cyanides, Lead, Arsenic
Chemical Industries	23	Acids, Alkalis, Ammonia
Sugar Industries	16	SS, high BOD
Paper & Pulp Industries	05	Chlorine, Mercury, SS, BOD, Phenol
Fertilizer Industries	05	Ammonia, Arsenic, Chromium, Urea
Distilleries	03	SS, high BOD
Cement Industries	03	SS
Total	903	

SS=Suspended solids, BOD=Biological oxygen demand the fishing industry both quantitatively and qualitatively; i.e., quantitatively by affecting the natural productivity of fisheries, and qualitatively by affecting the value of such organisms as food. Most of the industrial effluents contain constituents that are harmful to fishery organisms and, through consumption of them, to human life.

a. Paper and pulp industries

Paper and pulp industries are the major industries in Bangladesh. These industries depend on forests and agricultural residues (jute cuttings) for the supply of fibrous raw materials. The Karnaphuhi paper mills and the Karnaphuli rayon complex is the target chemical industry located on the shore of the Karnaphuli River in Chittagong region. There are three large paper industries and a number of smaller paper and paper products industries. In these mills there was no external treatment plant for effluents. The wastes from the process plants include discharge from washes etc. The dissolved dyes and other impurities impart a brown colour to the water. The waste water is called "black liquor". Facilities to recover "black liquor", generated by cooking bamboo and wood chips, and by bleaching systems, are most inadequate. These plants also dump solid wastes, fibre, wood particles, solids and inorganic compounds into the river. The Khulna newsprint mills, hard board mills from the Khalispur industrial belt, discharge untreated wastes directly into the Bharib river (ESCAP, 1988). These mills continuously discharge nearly 4,500$m^3 h^{-1}$ of waste water containing high levels of suspended solids (300 to 500 ml l^{-1}) and sulpher compounds. Occasional fish kills from the Kushiyara River in Sylhet have been reported due to effluents discharged by the paper mill near Fenchuganj (BHOUYAIN, 1983).

b. Urea fertilizer industries :

Bangladesh is blessed with natural soil fertility for crop production. Labour intensive farming, supplemental with organic fertilizer and green manure comprise traditional farming practices. Urea, triple super phosphate (TSP) and murate of potash are the major chemical fertilizers used in Bangladesh. The total amount of fertilizers used annually in Bangladesh, about 1.5 million tons increased over 20% during the preceding four years (REAZUDDIN, 1990).

Urea fertilizer industries constitute the largest industry and as individual units these are world size units. All these units discharge effluent waste water into large following rivers. Ammonia in effluent water comes from a variety of sources, but in the context of Bangladesh, the chief sources are urea factories. A concentration of 1.2 to 3.0 ppm of free ammonia or ammonia base is toxic but its hydrolysis into ammonia causes toxicity to aquatic species. Fish kills caused by the effluents from a urea fertilizer factory on the shore of the Sitalakhya River near Dhaka from March to April has become a regular phenomenon in recent years. The scientists of the Department of Environmental Pollution Control have recorded an ammonia level of 200 ppm in the Sitalakhya River at the sites of fish mortality (BHOUYAIN, 1983). Fish caught from the river downstream of the mill site reportedly emit a strong foul odour making them unfit for human consumption (REAZUDDIN, 1990).

c. Leather tanning industries

The leather tanning industry, an important foreign exchange earner, has some 170 tanneries of small, medium and large sizes with a total annual production of 7 million square meters of leather from 10 million cow, goat, sheep and buffalo (RAHMAN, 1993). It may be noted that 30% of total raw hide production takes place during the Eid-ul Azha festival. Waste water from the leather tanning industry contains some of the most offending pollutants. These untreated waste waters from this area are discharged into the Buriganga River. The combined waste water from tannery is highly coloured, due to the presence of vegetable tan liquor, and foul smelling. It is also alkaline and contains high concentrations of suspended and dissolved solids. Current estimates are that 40 metric tons of solids waste (sodium sulfide and chromic sulfide) are produced daily in the area and that 50% is hazardous due to its high chromium content. These chemicals are highly toxic and chromosol is bioaccumulated in food chain. Quite a large quantity of the processing chemicals enter waste water and is discharged without treatment into the river directly.

The highly in soluble chromium is damaging throughout the area, in particular in the river and flood plain that receives the waste water discharges from the tanneries. The huge amount of toxic pollutants discharged into the Bay of Bengal threatens marine life. The chromium concentration in the surface water of the Bay of Bengal is 2.20 ppm, dangerous to the marine biota.

d. Textile industries

Dyeing and finishing processes are two important steps in the textile manufacturing process. However, in the dyeing and finishing processes, a considerable amount of waste water is generated. Textile waste water contains notoriously toxic substances, like chromium from dyes. Chlorine and fungicides in contribute to high alkalinity, colour and an oxygen consuming organic load. In the textile dyeing and printing industries in Bangladesh, 2.5 to 3.5 thousand metric tons of dyeing chemicals are used. A fraction of these chemicals contain heavy metallic compounds which are toxic and have persistent in the environment. Due to discharge of large volumes of putrescible organic wastes, long stretches of these have developed anaerobic conditions, making the water unfit for drinking, agriculture, fisheries and other uses.

e. Sugar Industries

The sugar industry is another important agriculture-based industry in Bangladesh. About 2% (0.4 to 0.5 million acres) of total arable land is used for sugarcane cultivation and it is unlikely that this area will be further increased. Sometimes fish mortalities were found in waterways near Mobarakganj sugar mills in Jhenadah and Setabganj sugar mills in Dinajpur district due to the effluent discharges from these mills (ALI, 1991).

Environmental standards and present pollution status at urea plants, tanneries, textile mills and sugar mills of Bangladesh are shown in Table 6.

2.2. Thermal pollution

Thermal pollution is potentially one of the most critical of all water pollution problems. Thermal pollution may result from the heat discharged into receiving waters. The extent of thermal pollution chiefly depends on the volume of receiving water. The power plants at Ghorasal and Siddhirganj are two sites that pose significant threats of thermal pollution to the Sitalakhya river. The site at Ghorasal is particularly vulnerable where the cumulative power generation would be about 1000 MW. When condenser water from power plants is discharged directly into rivers, 50% or more of the cross sectional area or volume of flow of river water should be free of significant temperature increase due to heat additon to provide a pathway for fish and to ensure survival of free floating and drifting fish eggs, larvae and other organisms that are temperature sensitive. Several reports have appeared from time to time in newspapers regarding heavy mortality of fish in the Sitalakhya River.

2.3. Agrochemical pollution

Bangladesh is one of the important rice growing agricultural countries. With the advancement of scientific knowledge, the use of fertilizers and insecticides for higher crop yields are increasing day by day. Growing demands for rice for an ever increasing population has led to the modernization of agriculture. Irrigation and use of fertilizers and pesticides are essential for the present agriculture. The pollution hazards for aquatic life are increasing significantly with the widespread use of pesticides in agriculture. The area of land covered by deep water rice is over 2×10^6 ha (HAQUE *et al.*, 1992). The ecosystem of this area is highly seasonal, i.e., it remains under water for 5 months and contribute to fish production (DOF., 1986).

The first pesticide was introduced to Bangladesh in 1957. More than 250 pesticides (insecticides, fungicides, herbicides, nematicides, acaricides, algicides, etc.) are presently available in the market, but their recommended doses and toxic effects on fish are not clearly known (ALAM, 1995). ALAM *et al.*, 1995 have

Table 6. Environmental standards and present pollution status for urea factories, tanneries, textile mills and sugar mills of Bangladesh.

Parameters mg/l	Standard	Industry			
		Urea	Tanneries	Textile	Sugar
pH	6.5–8.5	9.12	4–10	8–11	4.6–7.1
Temperature	20–30℃	40℃	–	–	–
Acidity	<20	–	–	–	–
Alkalinity	70–100	–	475	300–900	–
Ammonia	0.025	–	–	–	–
NH_3-Ammonical nitorogen (as N)	1.2	300	12–1,970	–	–
Urea	–	2500	–	–	–
BOD	6.0	–	–	200–600	2200
COD	–	150	9,600	–	4380
Carbondioxide (dissolved)	6.0	–	–	–	–
Chloride (Residual)	0.01	–	–	–	–
Chloride	600	–	175–18,000	–	–
DO	4–6	–	–	–	–
Flow (m^3/h)	–	400–800	–	–	–
Hardness (as CaCO3)	80–120	–	–	–	–
Chromiun (total)	0.05	25	2.6–2,800	up to 3	–
Coliform (total, mg/100ml)	5000	–	–	–	–
Total solids	<1500	8600	–	1000–1600	3500
SS	25	–	–	30–50	800
Copper	<0.4	–	–	–	–
Lead	0.05	–	–	–	–
Mercury	0.001	–	–	–	–
Nitrite	0.03	–	–	–	–
Oil & grease	0.01	–	–		

Source : Rahman (1993)

reported that the number of registered rice pesticides marketed in Bangladesh was 66; 25 are used in significant amounts by the paddy farmers. The most commonly used pesticides in Bangladesh are shown in Table 7. The indiscriminate use of those pesticides on our crop fields may pose a serious threat to our potential aquatic resources. In Bangladesh there are huge areas that undergo shallow to medium flooding conditions (flood depth of 0.3 to 1.8 meters respectively during the flood monsoon). These areas are potentially suitable for integrated farming. Rice-cum-fish culture is a unique way of diversifying food production and increasing the income of farmers. Organophosphorus, organochlorine, carbamates, pyrethorids are among hundreds of poisonous chemicals that farmers have been spraying on their crops to fight against insects and pests.

In the rainy season, most small fishes migrate towards the flood plain and use the crop fields as spawning and nursing grounds for a certain period of time. Hence, the application of pesticides in improper doses kills almost all the fishes. Due to pesticidal pollution, the natural breeding and nursery grounds have become endangered, and ultimately, the breeding behaviour and reproductive cycle of fishes will also be changed. Most of the farmers are reported to have caused mortality of fishes in the paddy fields due to the use of pesticides. The indiscriminate use of pesticides surely affects the non-target organisms, including fish. This is one of the major causes of declining fish populations in the natural habitats of Bangladesh.

Organophophate and carbamate group pesticides used in Bangladesh have shorter soil residence times than do organochlorines. In the

Table 7. Pesticides used mostly in Bangladesh.

Granular	Liquid
*Basudin-10G	Aerovin-80WP
Furadan-5G	Aeromal-57EC
Curatex-3G	Bidrin-24SCW
Ekalux-5G	*Decis-2.5EC
*Diazinon-14G	*Diazinon-60EC
Padan-10G	Dimecron-100EC
	*DDVP-100EC
	*Dieldrin-20EC
	Ekalux-25EC
	Elsan-50EC
	Fyfanon-57EC
	Lebaycid-50
	Malathion-57EC
	Marshall-20EC
	Mipcin-75WP
	Nogos-100EC
	*Ripcord-10EC
	Roxion-40EC
	Sumithion-50EC
	Zithiol-57EC
	*Cymbush-10EC
	*Sumicidin-20EC

*Extremly hazardous to fish at the dose recommended by each chemical company.

case of organophosphorus pesticide use, the phosphates released promote eutrophication. In Bangladesh, organophosphorus pesticides are commonly used by the farmers in crop fields to control insects and pests. These chemicals end up in the water bodies after being washed away with the rain water, or flood water and are likely to have harmful effects on fish food organisms, fish eggs, larvae, fry and other aquatic life. In heavily polluted water bodies, pesticides or the products of their decomposition are invariably present among many different residues. It has been assumed that 25% of the total amount of pesticides used may reach the coastal waters and cause seawater pollution (ESCAP, 1988). Therefore, the pollution load in the Bay of Bengal in the form of pesticide residues is about 1800 tons yr^{-1} (MAHMOOD *et al.*, 1992).

A DDT manufacturing factory operating in Chittagong produces 100 tons of DDT daily. DDT was banned in Bangladesh 10 years ago, but it is still used for public health purposes, reportedly used for mosquito control, although many developed countries have either restricted or totally banned its use. This DDT is also reported to be used clandestinely as an adulterating agent by local formulators and dealers. Effluents from the DDT plant is drained into the river system directly via a ditch. DDT affects the photosynthetic capacity of certain algae and thereby interferes with primary productivity in the aquatic environment. It is estimated that half life of DDT in an ecosystem is 10 to 15 years. At high concentration, DDT's effects range from mortality to retardation of growth, impairment of reproduction in fish and invertebrates, increase in fish thyroid activity and reduction of natural compensatory reaction to stress and diseases.

Chemical insecticides and pesticides affect fish life in various ways, causing direct death of fish in different stages of their lives. The use of halogenated hydrocarbons as herbicides and pesticides, including DDT, is of special concern for fisheries.

2.4. Municipal wastes

The cities and human settlements in the coastal areas of Bangladesh do not have any domestic waste treatment facilities. Therefore, the human effluents, either directly or indirectly, find their way untreated into the rivers and eventually to the Bay of Bengal (ESCAP, 1988). Every day a considerable amount of blood and viscera of about 400 slaughtered animals from the Firringhee Bazar and Dewan hat slaughterhouse find their way into the River Karnaphuliy. KHAN and KHANAM (1992) recorded BOD levels in the Chaktai canal of Chittagong and the Karnaphuliy river estuary as 255 to 540 mg l^{-1} and 0.70 to 3.4 mg l^{-1} respectively.

Through transport of organic matter in the sewage in moderate quantities, some fertilization of fishing grounds takes place. In many fishing areas, the productivity of the water is derived exclusively from the discharge received from the land. The very high productivity of the Bay of Bengal is considered to be enhanced by the discharge of various types of organic sewage carried in by most of the major rivers of the sub-continent and beyond. However, excessive concentrations of organic putrescible substances can seriously damage fisheries, if oxygen, present in limited quantities, is used up in the process of putrefaction, thus creating zones which may be devoid of fisheries organisms. Further, excessive fertilization of water bodies encourages the production of poisonous plankton species resulting in toxic concentrations in fisheries products sold for human consumption. In addition, untreated sewage in huge quantities may cause unacceptable concentrations of pathogenic organisms locally in waters, which are otherwise very rich in nutrients. AHMED (1985) stated that the mortality of fish and other aquatic life in the Buriganga River was a result of deoxygenation and toxic gases.

2.5. Oil pollution

Oil pollution is a potential threat to the aquatic environment. It results from the crude oil transport systems, waste oil from ships and mechanised vessels, refining, handing losses, etc. Generally, more than 50% of the oil pollution in the aquatic environment comes from urban activities and through run-off. International oil tanker routes in the southern Bay of Bengal also contribute to the oil pollution in the marine coastal environment, which occurs due to wreckage of oil tankers and accidental oil spills. It has been estimated that 1700 million tones of oil is transported across the oceans annually ; estimates of oil influx to oceans vary between 2 and 5 million times a year, i.e., between 80 to 200 litre of oil is spilled somewhere in the ocean every second (JICA 1997). In Bangladesh, localised oil pollution is said to be heavy in the vicinities of Chittagong and Chalna ports. More than 1200 ships and 40 to 50 oil tankers in Chittagong port and about 600 ships in Mongla port are handled annually.

According to the department of shipping, about 2500 registered power driven river crafts and numerous unregistered small power boats, including oil tankers, ply the coastal waters of Bangladesh. In addition to these, the number of power driven trawlers and other boats engaged in fishing in the Bay of Bengal is about 3000. Different types of waste oil like ballast and bilge water from ships, tankers, mechanized boats, etc. and crude oil leakage, oil emulsion and oil residues from other sources are entering the water bodies of the marine environment. Ship breaking operations in Chittagong and Mongla are also responsible for oil pollution.

Oil pollution affects different species of organisms in different ways. The thin layer of oil on the water surface reduces light penetration and the exchange of oxygen and carbon dioxide across the air-sea interface, inhibiting photosynthesis and causing depletion of dissolved oxygen. It is reported that fish eggs and larvae may be killed at concentrations ranging from 10^{-5} to 10^{-3} ml l^{-1} of oil. Other studies have shown that fish eggs develop abnormally at oil concentrations between 1 and 10 ppm. At a concentration of 0.01 ppm, fish eggs hatch irregularly and late, and larvae from such eggs may be deformed. Some other sublethal effects are behavioural disturbance, changed migratory patterns and disturbed reproductive patterns. Larval stages of marine invertebrates are 10 to 100 times more sensitive to oil than adults.

2.6. Solids and sludges

Solid wastes generated from chemical industries may pose some difficult disposal problems. Small scale enterprises such as metal working, machine tools, and dyeing are frequently among the offenders for environmental degradation. Often such enterprises dump their wastes in their neighbourhoods. Such neighbourhoods often consist of shanty towns and, in the absence proper land use planing and regulations regarding location of industries, the informal sub-sectors cause considerable local degradation. Thus for example, TSP plant generates large amounts of gypsum as a reaction byproduct. The utilization of this gypsum has been limited and dumping of large amounts of gypsum is a problem due to unavailability of adequate space.

Sometimes rubbish of various kinds is carried with currents or just thrown into the river systems from the banks, vessels, dwellings, etc. These effluents are kitchen wastes, remains of cargoes and packaging, engine room wastes, wire bottles, plastics, and other objects. Use of non-biodegradable plastic products, such as plastic shopping bags, disposable syringes, bowls, nets, nylon ropes, packing items, etc., are increasing day by day and cause pollution in the country. In Dhaka alone, there are nearly fifty plastic factories which produce about 7 to 7.5 million polythene bags daily (IBRAHIM, 1992). It is reported that plastic bags and other products are also dumped directly in the Chittagong and Mongla port areas. Plastic is an harmful as oil spilage for marine biota.

2.7. Microbial contamination

Fish in common with all other organisms, are afflicted with a wide variety of bacterial and viral diseases. In the polluted water of the Karnafuli river estuary near sewage disposal areas, as many as 18 thousand coliform bacteria 100 ml^{-1} were reported, which is far higher than safe levels recommended by WHO. The large-scale microbial contamination of our water bodies that resulted in 1987, in heavy morality of the fish stocks, due to what has been called "Epizootic ulcerative syndrome", calls for special attention. The disease affects fishes such as *Puntius, Channa, Labeo, Catla*, and their juveniles. An investigation was done to identify the causative agents and to study the epidemiology of the disease, but the results are not yet conclusive.

3. Conclusion

In present days, there is talk everywhere on pollution. "Prevention is better than cure"-is a proverb in medical science. This proverb also holds true in pollution control. It is obvious that water bodies of Bangladesh are directly or indirectly becoming polluted due to input of so many polluting agents. We do not know how much heavy metals we are accumulating each day.

Therefore, the proper management of natural resources is essential to protect the environment. A sound environmental policy supported by necessary regulation is necessary now. However, a thorough survey of the impact of environmental degradation on fisheries should be carried out before definite recommendations are made. We must remember that we do not have much time left.

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Société franco-japonaise d'océanographie, Tokyo

学　会　記　事

1. 1997年12月9日（火）　日仏関連学会連絡協議会が日仏会館で開かれ，本学会からは高木副会長と佐伯幹事が出席した．

2. 1997年12月24日（水）　東京水産大学において平成9年度学会賞受賞候補者推薦委員会（第2回）が開かれ，推薦のあった候補者について業績等についての審議を行ったが，今回は候補者の決定に至らず後日再度委員会を開催することとした．

3. 1998年1月5日（月）　東京水産大学において平成9年度学会賞受賞候補者推薦委員会（第3回）が開かれ，前回に引き続き推薦のあった候補者の研究業績についての審議の結果，前川行幸会員（三重大学）が最適者との結論に達し，この結果を会長へ報告することとした．

4. 平成10，11年度評議員選挙が行われた（公示11月29日，投票締め切り1月10日，開票1月19日）．開票結果は下記のとおり．
   1）投票総数　59通　1993票
   2）有効票数　1992票（無効票数1）
   3）得票結果（47位までは同得票同順位，47位以下は抽選による）
   （（　）内は得票数）

1　（45）有賀祐勝
2　（40）松山優治
3　（37）柳　哲雄
4　（34）石丸　隆，平　啓介，谷口　旭
7　（33）山口征矢
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21　（26）長島秀樹，和田　明
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26　（24）岸野元彰
27　（23）有元貴文
28　（22）平野敏行，前田明夫，坂本　亘
31　（21）森永　勤
32　（20）前田昌調，前田　勝，中田喜三郎，大塚一志，寺本俊彦
37　（19）金成誠一
38　（17）福田雅明，磯田　豊，梶浦欣二郎，隆島史夫，山崎秀勝
43　（16）青木三郎，糸洌長敬，黒田一紀，丸茂隆三，高野健三
48　（15）高木和徳
49　（15）佐藤博雄
50　（15）渡邊精一
51　（15）宇野　寛
52　（14）木谷浩三（次点）
53　（14）竹松　伸
54　（14）畑　幸彦

（55位以下省略，大塚一志氏は辞退のため51位宇野寛氏まで当選）

5. 1998年2月10日（火）　日仏会館において日仏会館フランス事務所主催，本学会共済で，元日仏会館フランス学長（本学会顧問）のユーベル・セカルディ氏による講演会「フランスの養殖における最近の進歩と問題点」が開催され，多数の聴衆の参加があった．

6. 新入会員（正会員）

氏　名	所　属・住　所	紹介者
田畑　彰久	北海道大学大学院工学研究科 都市環境衛生工学講座 〒060-0813 札幌市北区北13条西8丁目	森永　勤
鈴木　亨	（財）日本水路協会 海洋情報研究センター 〒104-0061 東京都中央区銀座7-15-4　三島ビル5F	松山優治

7. 会員所属・住所等変更（正会員）
市川　香　九州大学応用力学研究所
〒816-0811
福岡県春日市春日公園6-1

8. 退会（正会員・受付順）
梶原昌弘，小林和男，水鳥雅文

9. 受贈図書（受付順）
勇魚　17
NTT R&D 46，47（3）

農業工学研究所年報　9
水産工学研究集録　6
東海大学海洋研究所研究報告　17, 18
東海大学海洋研究所年報　17, 18
イカ類資源研究会議報告　36
日本における1990年までの動物プランクトン現存量
RESTEC　40
養殖研ニュース　36
広島日仏協会報　139, 140
なつしま　151
Bulletin of the National Sccience Museum　23（4）
Polychaetous Annelids from Sagami Bay and Sagami Sea Collected by the Emperor Memorial Institute, National Science Museum, Tokyo
Journal of the Korean Society of Oceanography 32（2）
青島海洋大学学報　27（3, 4）
海洋与湖沼　28（5, 6）
韓国海洋学会報　32（3）

日仏海洋学会役員・評議員
（1996～1997年度）

日仏海洋学会会則

昭和35年４月７日　制定
昭和60年４月27日　改正
平成４年６月１日　改正

第１条　本会は日仏海洋学会と称する。

第２条　本会の目的は日仏海洋および水産学者の連絡を密にし，両国のこの分野の科学の協力を促進するものとする。

第３条　上記の目的を実現するため本会は次の事業を行なう。

⑴　講演会の開催

⑵　両国の海洋学および水産学に関する著書，論文等の相互の翻訳，出版および普及

⑶　両国の海洋，水産機器の技術の導入および普及

⑷　日仏海洋，水産学者共同の研究およびその成果の論文，映画などによる発表

⑸　両国間の学者の交流促進

⑹　日仏海洋，水産学者の相互の親睦のために集会を開くこと

⑺　会報の発行および出版

⑻　その他本会の目的を達するために必要な事業

第４条　本会には，海洋，水産学の分野に応じて分科会を設けることができる。

分科会は評議員会の決議によって作るものとする。

第５条　本会の事務所は日仏会館（〒150　東京都渋谷区恵比寿３丁目９番25号）に置く。

第６条　本会に地方支部を置くことができる。

第７条　本会会員は本会の目的に賛成し，所定の会費を納めるものとする。

会員は正会員，学生会員および賛助会員とする。

第８条　正会員会費は年額6,000円，学生会員会費は年額4,000円，賛助会員会費は一口年額10,000円とする。

第９条　本会は評議員会によって運営される。

評議員の定数は50名とし，正会員の投票によって選出される。選挙事務は別に定める選出規定による。

会長は評議員会の同意を得て５名までの評議員を追加することができる。

評議員の任期は２年とする。ただし，重任を妨げない。

第10条　評議員はその内より次の役員を選ぶ。ただし，監事は評議員以外からも選ぶことができる。

会長　１名，副会長　２名，幹事　10名，監事　２名

役員の任期は２年とする。ただし，重任を妨げない。

役員の選出方法は別に定める選出規定による。

第11条　本会に名誉会長，顧問および名誉会員を置くことができる。名誉会長，顧問および名誉会員は評議員会の決議により会長これを委嘱または推薦する。

日仏会館フランス人学長を本会の名誉会長に推薦する。

第12条　会長は本会を代表し，総会および評議員会の議長となる。会長事故あるときは副会長がこれに代わる。

会長，副会長および幹事は幹事会を構成し，本会の庶務，会計，編集，研究発表，渉外などの会務を行う。

監事は本会の会計を監督する。

第13条　年に１回総会を開く。総会では評議員会の報告を聞き，会の重要問題を審議する。会員は委任状または通信によって決議に参加することができる。

会長は必要に応じて評議員会の決議を経て臨時総会を招集することができる。

第14条　本会則の変更は総会の決議による。

日仏海洋学会評議員・役員選出規定

1．本規定は日仏海洋学会会則第９条および第10条に基づき本会の評議員および役員の選出方法について規定するものである。

2．評議員は正会員の50名連記無記名投票により選出する。
評議員の選挙事務は庶務幹事が行う。ただし，開票にあたっては本会役員以外の会員２名に立会人を委嘱するものとする。

3．会長は評議員の単記無記名投票により選出する。
会員選挙の事務は庶務幹事が行う。ただし，開票にあたっては本会役員以外の会員２名に立会人を委嘱するものとする。

4．副会長，幹事，および監事は，会長の推薦に基づき評議員会で決定する。

5．本規定の改正は評議員会の議を経て行う。

日仏海洋学会賞規定

1．日仏海洋学会賞（以下「学会賞」という）を本学会に設ける。学会賞は本学会員で，原則として本学会誌に発表した論文の中で，海洋学および水産学において顕著な学術業績を挙げた者の中から，以下に述べる選考を経て選ばれた者に授ける。

2．学会賞受賞候補者を選考するため学会賞受賞候補者推薦委員会（以下「委員会」という）を設ける。

3．委員会の委員は13名とする。
委員は毎年春の評議員会で選出し，委員長は委員の互選により定める。
会長は委員会が必要と認めた場合，評議員会の同意を得て２名まで委員を追加委嘱することができる。

4．委員会は受賞候補１件を選び，12月末までに選定理由をつけて会長に報告する。

5．会長は委員会が推薦した候補者につき無記名投票の形式により評議員会にはかる。投票数は評議員総数の３分の２以上を必要とし，有効投票のうち４分の３以上の賛成がある場合，これを受賞者として決定する。

6．授賞式は翌年春の学会総会において行い，賞状，メダルおよび賞金を贈呈する。賞金は５万円とする。

7．本規定の改正は評議員会の議を経て行う。

覚　書

1．委員は各専門分野から選出されるよう十分配慮すること。

2．受賞者は原則として順次各専門分野にわたるよう十分配慮すること。

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Deadlines

- ♥ Camera ready abstract --- Oct. 1, 1998
- ♥ Registration ---December 1, 1998

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（正会員・学生会員）

	年度より入会	年　　月　　日申込
氏　　名 ローマ時		 年　　月　　日　生
勤務先	住　所　〒 機関名 電　話	
自　宅	住　所　〒 電　話	
紹介会員氏名		
送付金額　　　　円	送金方法	
会誌の送り先（希望する方に○をつける）	勤務先　　　自　宅	

（以下は学会事務局用）

受付	名簿 原簿	会費 原簿	あて名 カード	学会 記事

入会申込書送付先：〒150-0013 東京都渋谷区恵比寿 3-9-25

（財）日仏会館内

日 仏 海 洋 学 会

郵便振替番号：00150−7−96503

投稿の手引

1．「うみ」（日仏海洋学会機関誌；欧文誌名 **La mer**）は，日仏海洋学会正会員およびそれに準ずる非会員からの投稿（依頼稿を含む）を，委員会の審査により掲載する。
2．原稿は海洋学および水産学両分野の原著論文，原著短報，総説，書評，資料などとする。すべての投稿は，本文，原図とも正副2通とする。副本は複写でよい。本文原稿用紙はすべてA４判とし，400字詰原稿用紙（和文）に，または厚手白紙にダブル・スペース（和文ワープロでは相当間隔）で記入する。表原稿および図説明原稿は，それぞれ本文原稿とは別紙とする。
3．用語は日，仏，英３カ国語の何れかとする。ただし，表および図説明の用語は仏文または英文に限る。原著論文（前項）には約200語の英文または仏文の要旨を，別紙として必ず添える。なお，欧文論文には，上記要旨の外に，約500字の和文要旨をも添える。ただし，日本語圏外からの投稿の和文要旨については編集委員会の責任とする。
4．投稿原稿の体裁形式は最近号掲載記事のそれに従う。著者名は略記しない。記号略号の表記は委員会の基準に従う。引用文献の提示形式は，雑誌論文，単行本分載論文（単行本の一部引用を含む），単行本などの別による基準に従う。
5．原図は版下用として鮮明で，縮尺（版幅または1/2版幅）に耐えられるものとする。
6．初校に限り著者の校正を受ける。
7．正会員に対しては７印刷ページまでの掲載を無料とする。ただし，この範囲内であっても色彩印刷を含む場合などには，別に所定の費用を著者負担とすることがある。正会員の投稿で上記限度を超える分および非会員投稿の印刷実費はすべて著者負担（10,000円/頁）とする。
8．すべての投稿記事について，１篇あたり別刷50部を無料で請求できる。50部を超える分は請求により，50部単位で作製される。別刷請求用紙は初校と同時に配布される。
9．原稿の送り先は下記の通り。

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