ABSTRACT

INTRODUCTION

and global productivity, importance of recruitment for such species and fish availability for fishermen.

There is a need of knowledge on environment. Studies have been identified by the PELFISH initiators as early as 1990 but such programs on environment or productivity issues requiring specific means and skills could not be conducted. Thus we choose to gather and exploit existing informations. In a further publication we will give the results of the measurements performed during the fifteen **Bawal Putih I** acoustic cruises which happened between December 1991 and March 1994.

These horizontal transects and vertical stations should allow us to give a good description of the temperature and salinity variations during two successive annual cycles. Since global studies are quite old it will constitute an important contribution on environment issues. For now we will mainly refer to works such as Wyrtki's or Veen's, that is to say works which are 30 or 40 years old. Since that time only scarce and partial observations have been made. This paper is also an opportunity to point out the most obvious lacks.

Our contribution is not the first of this type on the Java Sea environment topic. More specifically, we relied on three papers and their, more or less, general description : Potier *et al.* (1989), Potier and Boely (1990), Boely *et al.* (1991).

1. GENERALL LANDMARK

1.1 Physical features

The great Sunda shelf extends from the Gulf of Thailand southward through South China Sea between Malaysia, Sumatra and Kalimantan, and the Java Sea represents its South-eastern part (fig. 1). It is a large and shallow water mass which has been exundated several times during Pleistocene (Emery *et al.*, 1972) when Sumatra, Java and Kalimantan where joined together with the Malacca peninsula.

Morphologically, the Java Sea is roughly rectangular (fig. 2). It is well delimited on three sides materialized by three huge islands : Kalimantan, Sumatra and Java. In its western part, it remains open with the Sunda Strait, between Sumatra and Java, giving way to the Indian Ocean and the Karimata Strait opening northward on the South China Sea. Obviously the eastern boundary has not the same meaning, as it is wide open toward the Flores Sea and the Makassar Strait.

This quick description already gives three essential features of the ecosystem :

- The discharge of continental freshwater is considerable through Kalimantan (mainly) Sumatra and Java rivers. It partly explains the low salinities encountered seasonally (cf. below, 2.1).
- The seasonal exchanges with the South China Sea through the Karimata Strait should not be underestimated, even if we don't follow Hardenberg (1937), who quoted Berlage calculations on the Java Sea being **"swept clear twice a year"**.

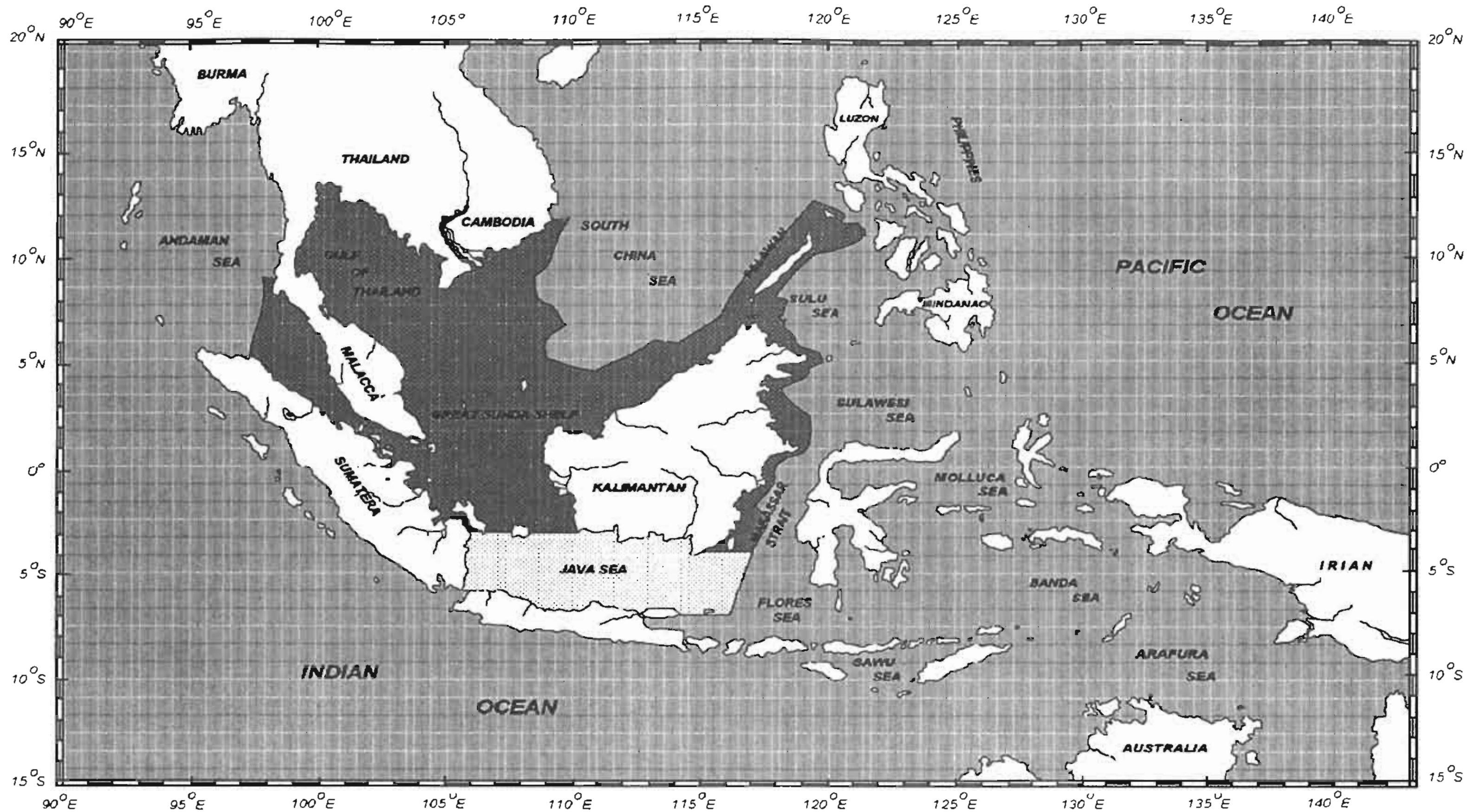


Figure 1

Great Sunda Shelf (<100 m) and Java Sea location

Letak Laut Jawa terhadap Paparan Sunda {<100 m}

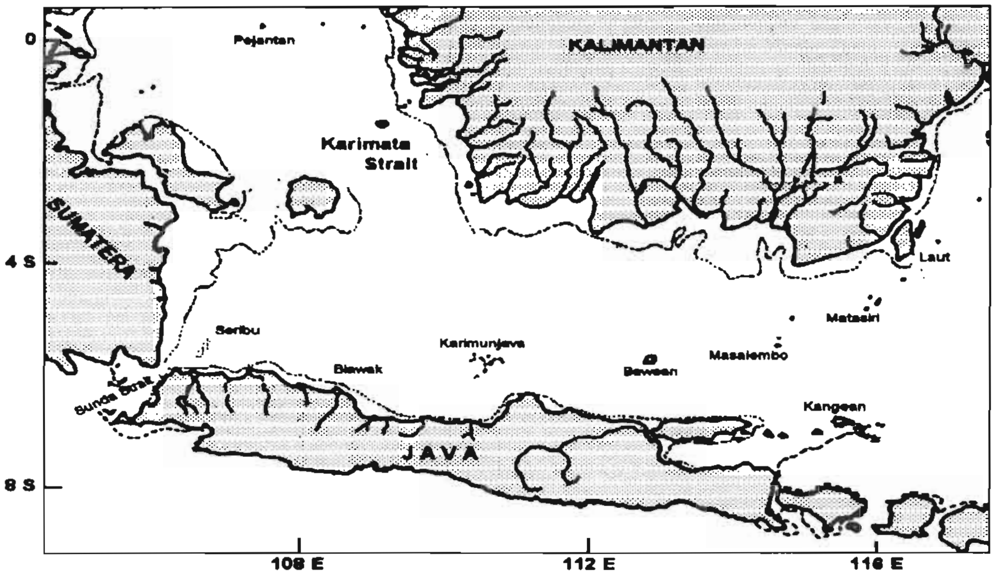


Figure 2a

JAVA SEA SURROUNDINGS AND TOPONOMY

PERAIRAN LAUT JAWA DAN BEBERAPA NAMA PULAU YANG PENTING

..... *20m isobath*

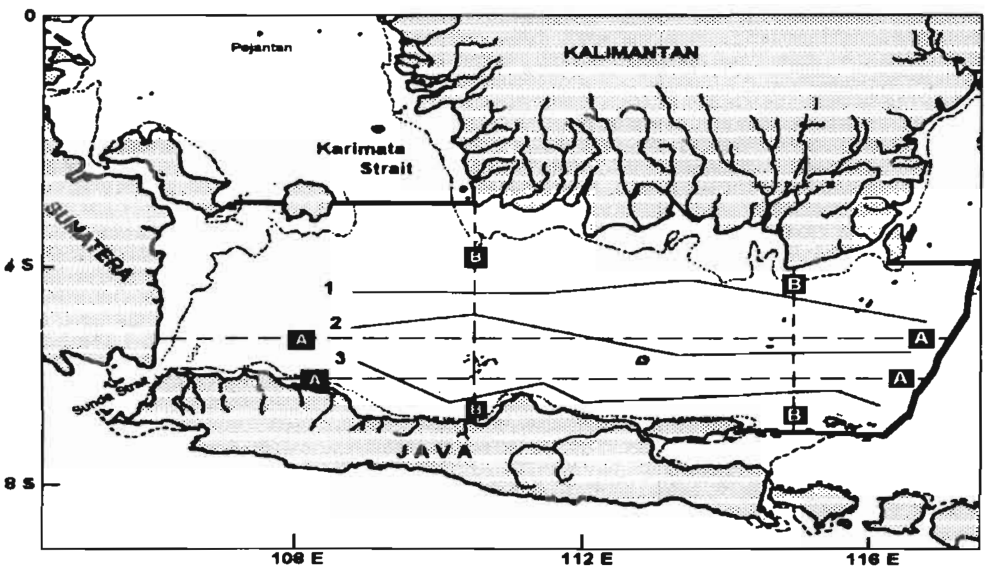


Figure 2b

LIMITS OF THE JAVA SEA AS DEFINED IN THIS ARTICLE

1,2,3 = Position of the transects of vertical profiles salinity

A-A,B-B= Positions of the bathymetric profiles

BATAS LAUT JAWA YANG DIMAKSUD DALAM TULISAN INI

1,2,3 = Posisi dari pada transek dari profil vertical salinitas

A-A,B-B= Posisi dari profil batimetrik

- The eastern delimitation of the Java Sea raises a main issue : what are the relations with the eastern part of the Indonesian Archipelago ?

From the above description we could give an estimation of the Java Sea total area. We choose to define Java Sea as the area of marine waters -for depth less than 100 meters- delimited by the coasts of Sumatra, Java and Kalimantan, latitude 3° South for the Karimata Strait and 4° South for the Makassar Strait (fig. 2b). Owing to planimetric processing we obtained 442 350 km^{-2}. In fact, one could ask if near the eastern border, the estimation should not include a large part of continental shelf in the Makassar strait (this northern extension represents 57 790 km^{-2} above 100 m deep). In the same way, the southern Bay of Madura (fig. 2a) could be taken into account : 10 000 km^{-2} less than 100 m deep. Even excluding the South China Sea, these few remarks demonstrate that for biologists and ecologists the Java Sea concept is not as clear as it is for geographers. It explains why the Java Sea area is sometimes given with different values from one paper to another.

The average depth of the Java Sea is about 40 m and in longitudinal axis, its bottom is slightly sloping toward East. The maximal depth is found North of the Madura Island (fig. 3a). It is interesting to notice that there is a clear dissymmetry between the coasts of Kalimantan and those of Java, with shallow waters much wider in the northern part than in the southern one (fig. 3b). According to the spatial definition given above, deep waters (i.e. more than 50 m deep) represent 156 000 km^{-2} (about 35% of the total area) whereas the coastal shallow ones, less than 10 m deep, cover 30 300 km^{-2} (nearly 7%).

From West to North-East many islands and/or coral reef lie in the Java Sea (fig. 2a) : Seribu, Biawak, Karimunjava, Bawean, Masalembo, Kangean, Matasiri. Except for the Seribu Islands they all correspond to pelagic fishery zones. According to Emery (1972) the bottom of the Java Sea is -mainly 90%- constituted of a deep dense mud layer. During the **Pechindon** campaign (Boely *et al.*, 1991), large beds of mud mixed with shell and coral debris were detected in the central part and South of Kalimantan. Near the coast, rocky outcrops associated with coral formations are observed.

1.2 Climatology

This general description of main climatic features, important for the understanding of the Java Sea functioning, comes from Potier *et al.* (1989).

The prevailing climate in the Java Sea is a typical monsoon climate marked by a complete reversal of the winds regime. This phenomenon is caused by differences in temperature between the continental and oceanic areas. The rainy monsoon occurs between mid December and March and is characterized by very windy periods with frequent rainfalls lasting for days. The dry monsoon occurs from June to September and is more regular. The climate varies considerably throughout this zone.

- WINDS

These are the essential feature of the climate. From November to February they blow from the North-West with an average intensity of 3 Beaufort. From May to September they blow in a South to South-East direction and are more regular, their force sometimes exceeding 4 Beaufort. During the transitional months they are light and very variable (fig. 4a and 4b). Land breezes may upset the general pattern.

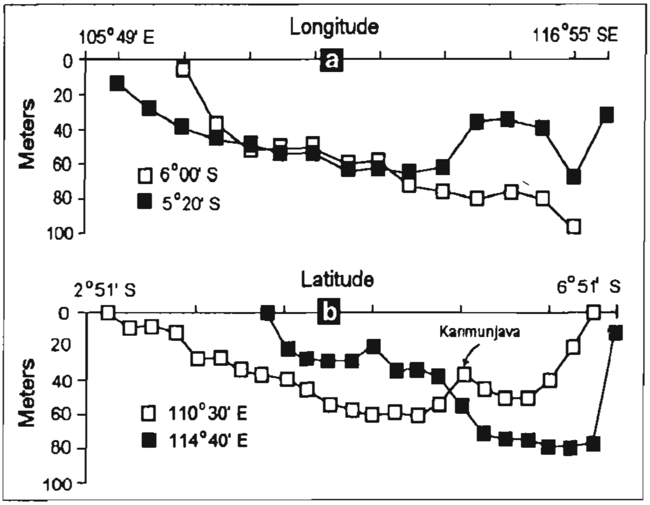


Figure 3a

LONGITUDINAL JAVA SEA BATHYMETRIC PROFILES

PROFIL IRISAN MELINTANG BATIMETRIK DI LAUT JAWA

Figure 3b

LATITUDINAL JAVA SEA BATHYMETRIC PROFILES

Profile location is indicated on fig. 2 b

PROFIL BATIMETRIK DI LAUT JAWA

Lokasi profil ditunjukan pada gambar 2b

■ RAINFALLS AT SEA

Rainfalls at sea follow a very peculiar rhythm (fig. 5). The rainy season lasts from December to March reaching its maximum in January and February. The dry season occurs from July to October with a characteristic minimum in September, sometimes less than 50 mm. There is a clearly marked West to East gradient (Wyrtki, 1955), the most abundant rainfalls being observed off the Sumatra and Kalimantan coasts. The average annual rate is 1 880 mm. The relative humidity decreases from February to November. Due to heavy rainfalls during the first two months of the year, it decreases during the transitional months, becoming light when the South-East monsoon sets in.

■ AIR TEMPERATURE

The intensity of the monsoon is indicated by the monthly means. In general, the temperature is lower when the monsoon is more regular and lasts longer. During the North-West monsoon, it comes with increasing rainfalls. The average monthly temperature is 27° C and the daily amplitude is much higher in the transitional months. Maxima are recorded between 12:00 and 16:00, except during the North-West monsoon when the extent of the cloud layer and the abundance of the rain cause many daily variations in temperature. Following a semi-annual rhythm, maxima are reached in the inter-monsoon periods whereas the minima correspond to the monsoon periods (fig. 6).

2. THE HYDROLOGICAL PARAMETERS : SALINITY AND TEMPERATURE

From the first investigations of importance by Van Veel (1923), various works and results have been produced. All are agreeing with the description of the average phenomena. More recently, since 1950, information originated from commercial ships (hydrological and meteorological measurements) allowed to establish maps with an average distribution of the parameters by geographic square.

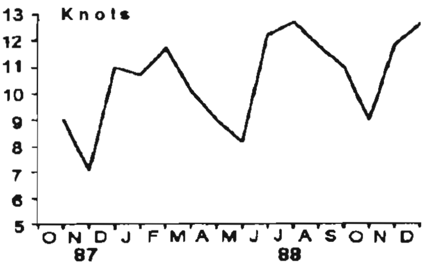


Figure 4a

AVERAGE VELOCITY OF THE WINDS IN THE JAVA SEA FROM OCTOBER 1987 TO DECEMBER 1988

KECEPATAN ANGIN RATA-RATA DI LAUT JAWA DARI OKTOBER 1987 SAMPAI DESEMBER 1988

SHIP data from Potier and Boely, 1990

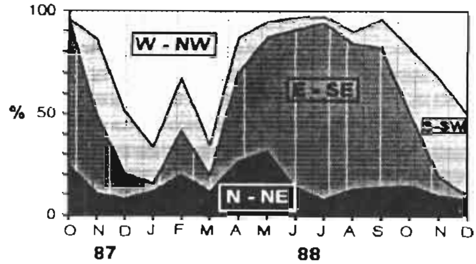


Figure 4b

MONTHLY DISTRIBUTION OF THE WINDS DIRECTION IN THE JAVA SEA FROM OCTOBER 1987 TO DECEMBER 1988

DISTRIBUSI BULANAN ARAH ANGIN DI LAUT JAWA DARI OKTOBER 1987 SAMPAI DESEMBER 1988

SHIP data from Potier and Boely, 1990

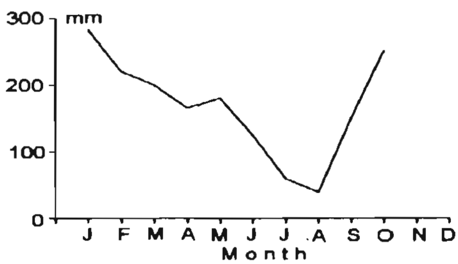


Figure 5

MONTHLY AVERAGE RAINFALL IN THE JAVA SEA

RATA-RATA CURAH HUJAN DI LAUT JAWA

From Wyrtki, 1956

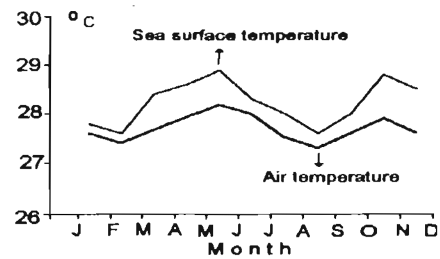


Figure 6

MONTHLY AVERAGE AIR AND SEA SURFACE TEMPERATURES IN THE JAVA SEA

RATA-RATA BULANAN SUHU UDARA DAN PERMUKAAN AIR LAUT DI LAUT JAWA

SHIP and Wyrtki data, 1956

Figure 7

THE POSITION OF THE 32 ‰ ISOHALINE

GAMBARAN ISOHALIN 32 ‰

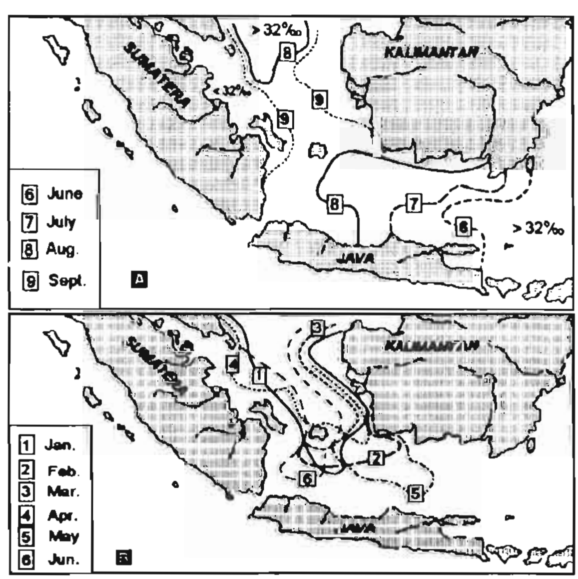
***A** : From June to September 1950 showing the advance of high salinity waters from the East*

Dari Juni sampai September 1950 memperlihatkan desakan masa dengan salinitas tinggi dari Timur

***B** : From January to June 1953 showing the position of the tongue of high salinity entering the Java Sea in North West mooson*

Dari Januari sampai Juni 1953 memperlihatkan posisi lidah masa air salinitas tinggi memasuki Laut Jawa pada musim Barat daya

(Wyrtki, 1961)



2.1 Salinity

From the classification established by Wyrtki (1956-1961), we can consider 4 types of waters circulating seasonally in the Java Sea.

- The oceanic water masses coming from the Pacific and the Indian oceans. Permanently present in the eastern part of the Indonesian archipelago, they can reach the Java Sea through the Makassar Strait or through the Flores Sea. Their salinity is more than 34‰. All the other waters have been more or less subject to a mixing. They are :
- "mixed" waters between 34‰ - 32‰, mixed waters from the South of the China Sea, or oceanic waters mixed with rainfalls or streaming in the Java Sea.
- "Coastal" waters between 32‰-30‰, like the diluted waters from the South of the China Sea by streaming along the East Sumatra or South Kalimantan borders.
- "River" waters below 30‰ which represent coastal waters more diluted at the mouth of rivers.

In reality, there are only two types of original waters in the Java Sea : one from the West (South of the China Sea) and one from the East, oceanic.

The moving and/or the formation of these types of waters are ruled by the alternative system of the monsoon : the wet monsoon from North-West, the dry monsoon from South-East.

From June to October, the dry monsoon blows from South-East. Rainfalls are scarce and limited. Figure 7A (Wyrtki, 1961) gives the progressive penetration of the oceanic waters into the Java Sea, by means of the retreat of isohaline 32‰. Figures 8a and 8b, from Veen, 1953, represent the progression of high isohalines westward.

From December to March, the wet monsoon blows. The waters from the South China Sea push off the waters in place and enter throughout the Karimata Strait. Figure 7B, from Wyrtki 1961, shows isohaline 32‰ moving toward the East during this season.

Owing to rainfalls and river outflows, an intense dilution develops, progresses from the coasts (Sumatra, Kalimantan) then reaches the whole Java Sea. Figures 8c and 8d, Veen 1953, show the increasing dilution whereas the South China Sea waters push is carrying on. In March diluted waters have overrun the Java Sea.

When in June - July the winds from the South-East monsoon blow again, the oceanic waters entering into the Java Sea, push on the diluted waters westward and toward the coasts. So by 107-108°E, we encounter two minima of salinity every year. (fig. 9, from Soeriaatmadja, 1956).

Compared with the oceanic annual variations, the average annual variations of the Java Sea are very large : from 30.8 to 34.3‰ in the eastern part, and from 30.6 to 32.6‰ in its western part, due to important discharges of the rivers (Kalimantan, Sumatra). The average minimum of salinity is near 31.8‰ from January to June, the maximum occurring in September (34‰) (Veen, 1953).

On an average, isohaline 34‰ moving eastward reaches the latitude of Semarang (111°E). Sixty per cent of the area would be covered by the waters from 32 to 34 ‰ all along the year, 15% of which being less than 32‰. Figure 9 (Soeriaatmja, 1956) gives a good illustration of waters permanently tending to be diluted with the western part from 109°E down to 33‰. But from one year to the other, due to important rainfalls, the variations of salinity concerns the maxima more than the minima.

2.2 Inner layers salinities

All the previous observations concern superficial and average measurements, whereas the depth of the Java Sea is about 40 meters. To our knowledge there is almost no deep hydrological measurements from the Java Sea excepted from **"Samudera"** (1956) but referring to the South coast of Kalimantan, and from **"Pechindon"** trips (1985) but located at the longitude of Karimunjava Islands.

During two recent trips in opposite season, some vertical profiles were assessed along three transects, with an automatic sensor profiler SEA BIRD and the average values by meter recorded. These positions are located in figure 2b. The data processing is still in progress but we can present here the first provisional results.

In October (fig. 10a), the North and South profiles show the presence of low dilution from the surface to 25 m depth, West of 111°E in the South, West of 109.30° E in the North. At the surface, isohaline 34‰ is significantly at the latitude of Semarang but further West in the northern part. All the water mass is occupied by waters more than 34.5‰ (maximum 34.7‰) until 113.3° E and even until the western limits of the observations. So at the end of the dry season at least half of the Java Sea waters would have been replaced.

In February-March, the dilution of the waters has already well forwarded but referring to Wyrtki's conclusions (fig. 7) the lowest salinity occurs one month later. At about 90 miles from the coast of Kalimantan (fig. 10b) we detected two zones of important low salinity; at the West, the first may continue throughout the West and represents the input of the low salinity waters from the Karimata strait; at the East, it is the low salinity waters from the complex of Barito rivers (Banjarmasin). In the North profile, the water salinity stands between 31.5 and 32‰ in the East; but they are more salted in depth in the West.

In the median transect, we found the same as in the North one, but the importance of higher salinity waters, in the West, increases. In the South transect, waters mainly have a 33-33.5‰ salinity. From this we observed at the entry of the Java Sea a clear pushing of salted waters near the bottom. In the South-West part, there could be waters more than 33‰, in full wet monsoon. It means that the Java Sea does not represent an homogeneous whole. During the year the northern half reveals high variations in salinity and is euryhaline (variations from 31 to 34.6‰) while the southern half, under permanent oceanic influence, has more limited variations (33-34‰). But we do not really know what is the evolution of the South-West part.

2.3 Temperatures

The following is adopted from Potier *et al.* (1989). The annual fluctuations of the surface temperature are relatively slight and the Java Sea has a great thermal stability with an annual average of 28° C and a gradient situated between 2° and 3° C (fig. 6) Usually during the North-West monsoon the highest temperatures are found in the East (Van Veel, 1923) and the lowest ones in the West along the coasts of Sumatra (influence of rainfalls). During the South-East monsoon this gradient is reversed and highest temperatures are then found in the West. The minima are observed in June-August and December-January (27°C), the maxima being

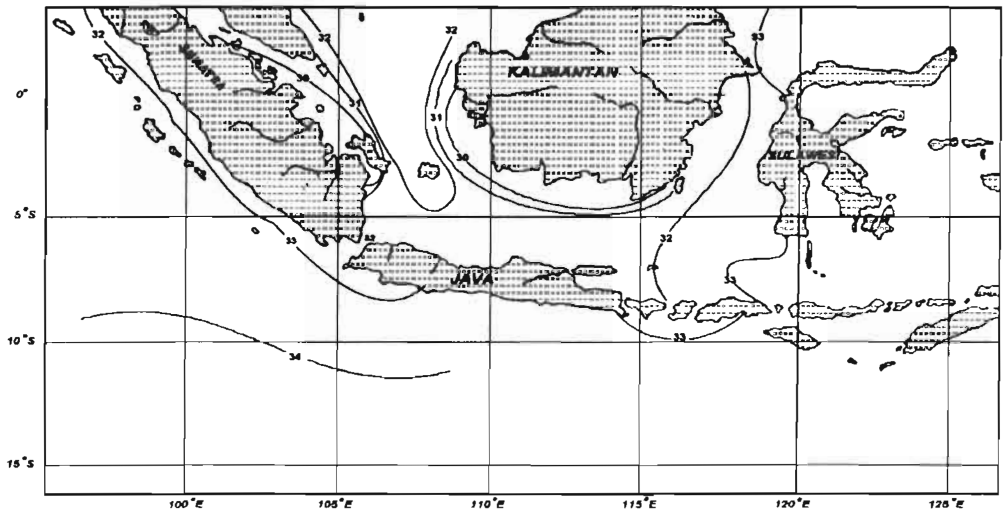


Figure 8a

AVERAGE POSITIONS OF THE ISOHALINES IN MAY (SURFACE SALINITIES)

POSISI RATA-RATA DARI ISOHALIN PADA BULAN MEI (KADAR GARAM PERMUKAAN)

(after Veen, 1953)

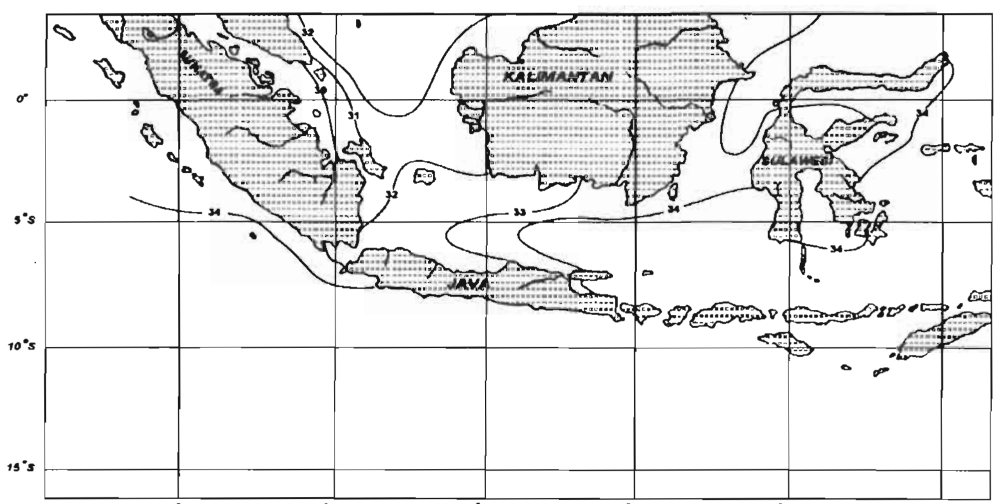


Figure 8b

AVERAGE POSITIONS OF THE ISOHALINES IN SEPTEMBER

POSISI RATA-RATA DARI ISOHALIN PADA BULAN SEPTEMBER

(after Veen, 1953)

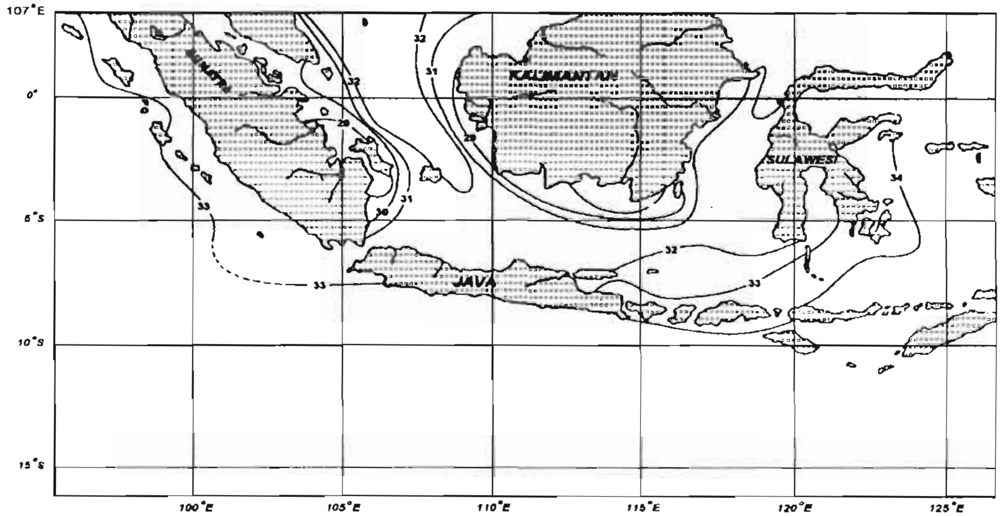


Figure 8c

AVERAGE POSITIONS OF THE ISOHALINES IN JANUARY

POSISI RATA-RATA DARI ISOHALIN PADA BULAN JANUARI

(after Veen, 1953)

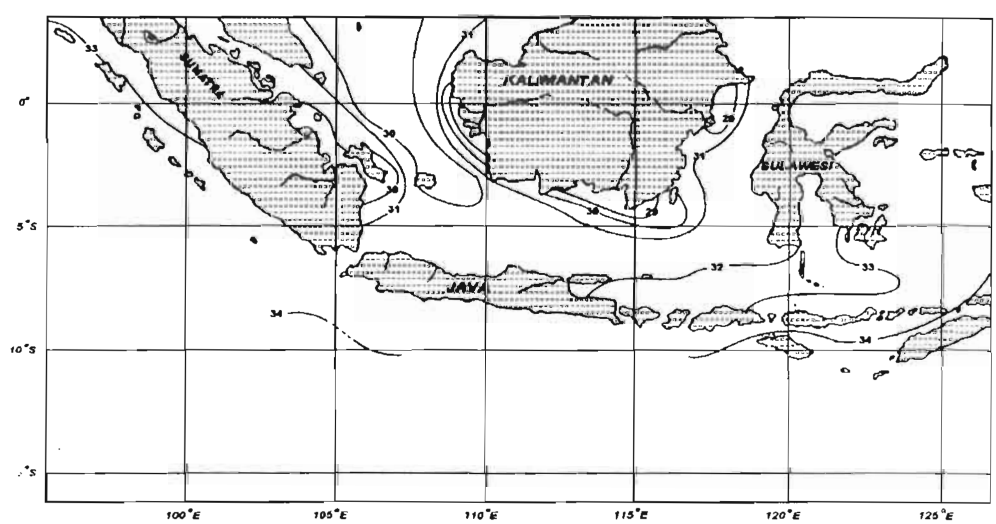


Figure 8d

AVERAGE POSITIONS OF THE ISOHALINES IN MARCH

POSISI RATA-RATA DARI ISOHALIN PADA BULAN MARET

(after Veen, 1953)

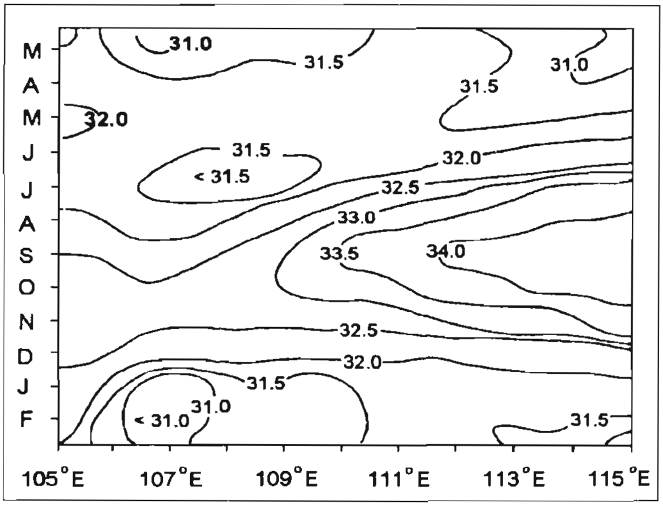


Figure 9

JAVA COAST ALONG THE YEAR EVOLUTION OF THE MEAN SALINITY BETWEEN 5° AND 6° S

EVOLUSI SALINITAS RATA-RATA ANTARA 5° DAN 6° LINTANG SELATAN, DI LAUT JAWA, SEPANJANG TAHUN

(after Soeriaatmadja, 1956)

recorded in April, May and November (30°C) in the inter-monsoon periods. The water mass itself is very homogeneous with slight thermal gradients from 1°C recorded in May 1985 during the **Pechindon** survey to 0,4°C recorded during the **Mutiara IV** campaigns (Losse and Dwippongo, 1977) in July-September. The vertical temperature stratification is not always found but no reverse phenomenon is observed. In the extreme eastern part of the region where depth exceeds 90 m a slight thermocline appears between 30 and 70 m at certain periods of the year (June-July). A study of the data provided by the Gosscompt charts, covering a period from June 1981 to December 1984 confirms these results. The data grouped per 1°15 * 1°15 squares show a noticeable homogeneity in latitude and longitude (fig. 11). The various cruises of the PELFISH Project do not bring further information.

3. THE CIRCULATION SCHEME

The development of a system of currents related to the winds in the Java Sea is favored by the orientation of its basin in relation to the direction the monsoon blows. The settling of the currents is directly in relation with the winds, except on the coasts of Sumatra and Java, where local phenomena related to geography could interfere (Wyrtki, 1961). It seems that these phenomena have not yet been studied (fig. 12) .

3.1 Surface currents

During the South-East monsoon (June-September) the currents flow to the West at low speed (0.5 knot). They reach up 1 knot off Belitung Island. During the North-West monsoon (December-March) the pattern totally reverses and currents flow toward the East (1-2 knot) (fig. 13a).

During the inter monsoon, the current would flow toward the West along the coast of Kalimantan whereas in the whole Java Sea, they would be toward the East. (fig. 13b).

This is the scheme usually accepted, as resulting from the climatic conditions. Nevertheless, as mentioned before, it seems that the phenomena do not always follow the general pattern.

Figure 10a

Java sea : W-E vertical profiles of salinity in October 1993

(position of transects in fig.2)

Profil vertical salinitas dari Barat ke Timur pada bulan Oktober 1993 di Laut Jawa

(posisi transek pada gambar 2)

In the North
Pada bagian Utara

In the middle
Pada bagian Tengah

in the South
Pada bagian Selatan

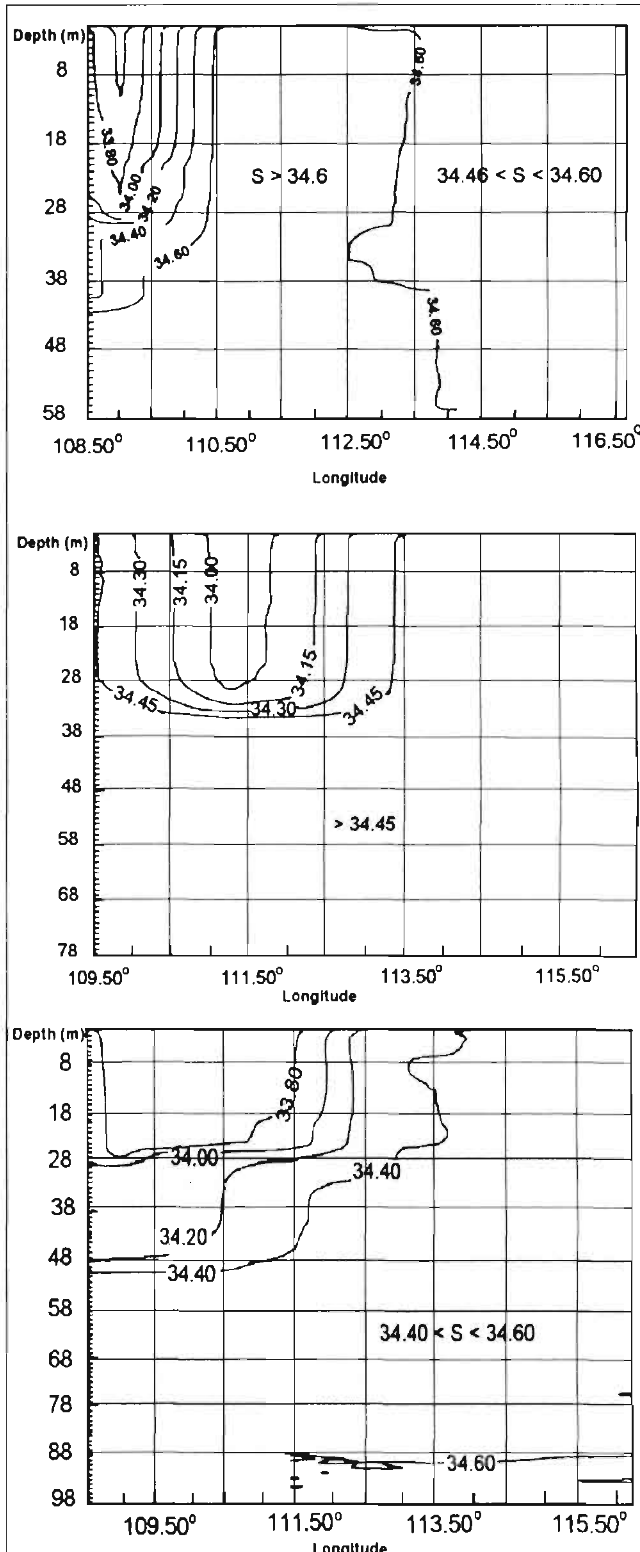


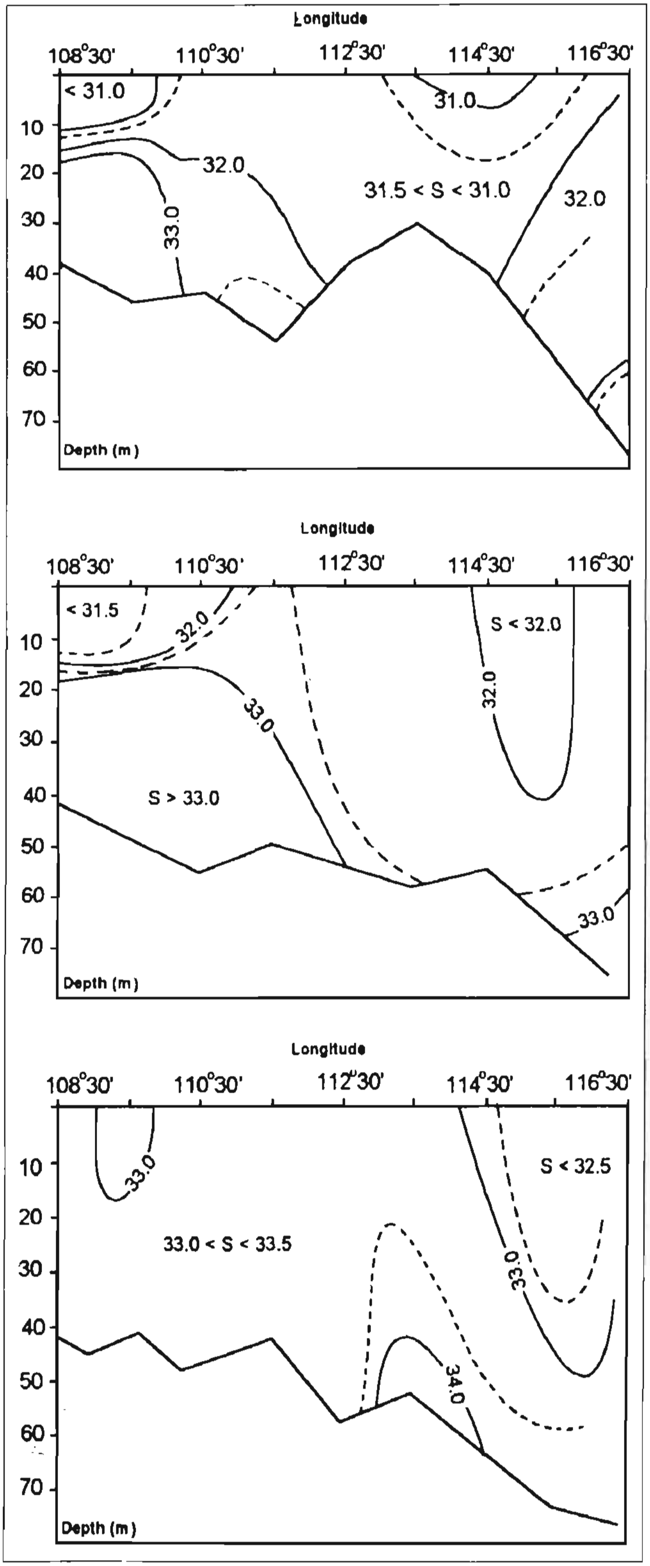
Figure 10b

Java Sea :
W-E vertical profiles of salinity in February 1994

Position of transects in Fig. 2

Profil vertical salinitas dari Barat ke Timur pada bulan Februari 1994 di Laut Jawa

Posisi transek pada gambar 2



In the North
Pada bagian Utara

In the middle
Pada bagian Tengah

In the South
Pada bagian Selatan

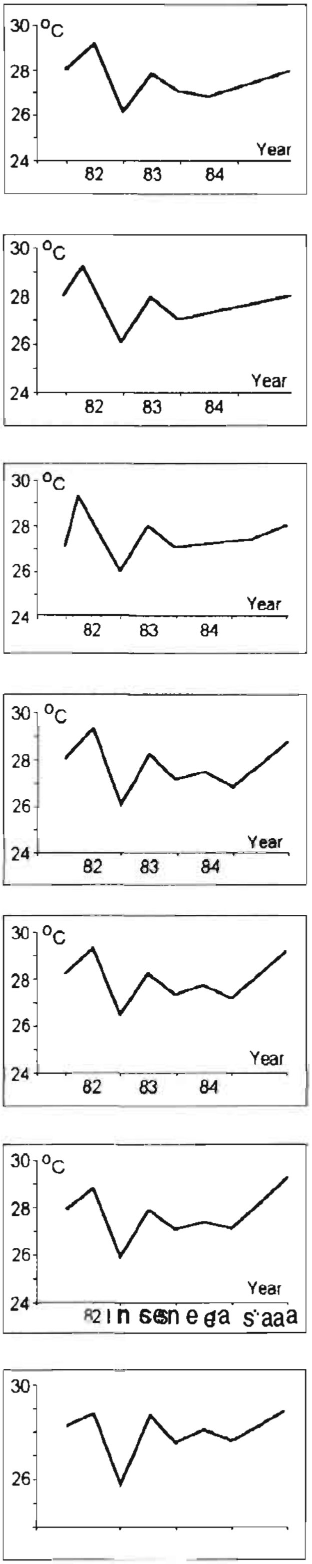


Figure 11

Evolution of the surface temperature from June 81 to June 85 in the Java Sea

Evolusi temperatur permukaan air laut dari Juni 1981 sampai Juni 1985 di Laut Jawa

(Gosscompt data), after Potier et al. (1989)

But to which extent? In February 1994 in the North-West of the Java Island (25 miles from the coast) in full West monsoon we met a superficial current toward the North-West. On the other hand, some people think that, during the inter-season the land winds can play an important role.

3.2 Inner layer currents

All the previous observations concern superficial and average measurements. Whereas the Java Sea is about 40 m deep, its whole East facade is open to influences from the Flores Sea, even if in the North-East bathymetry is less than 40 m in the South of Kalimantan.

As far as we know, no measurements of sub-superficial currents have been made in the Java Sea. Wyrtki (1961) considered that owing to depth of these shallow waters and to the winds steady at every season, the surface currents have to concern the whole water mass with the same celerity. But isohaline maps may contradict this early conclusion. The two groups of profiles we present (fig. 10a and 10b) clearly show that the system of underwater current do not entirely follow the superficial ones.

In October, the underwater currents clearly flow from the East but apparently their celerity seems higher in the North and the South where the salinity reaches the maximum values. Horizontal profiles at 10, 30, 40 m show that the current is entering from the North-East. But the most interesting are the vertical profiles from February (fig. 10b). That point out the quasi permanence of an underwater current from East during the wet season Otherwise how could we

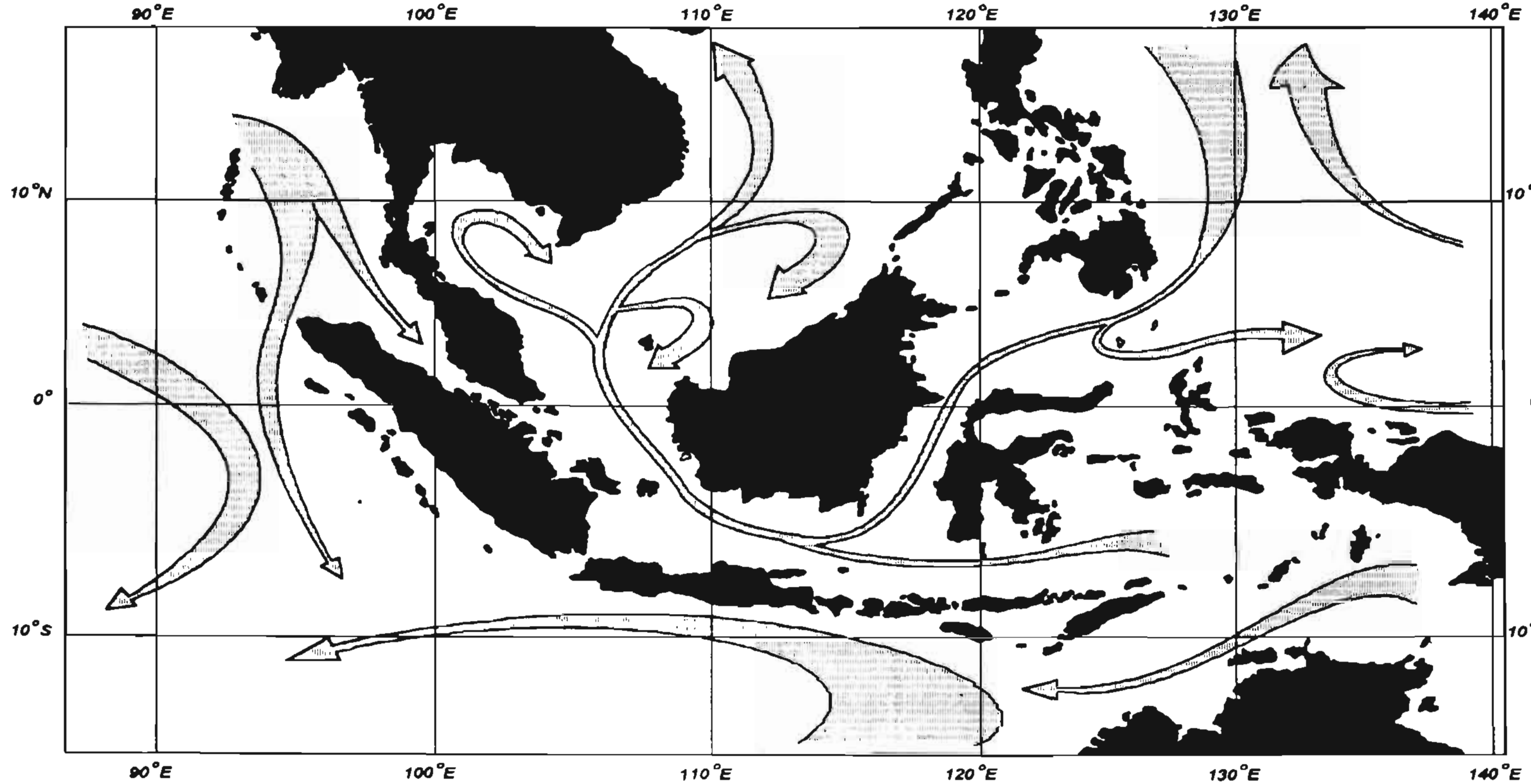


Figure 12

Surface currents in South Asia in August

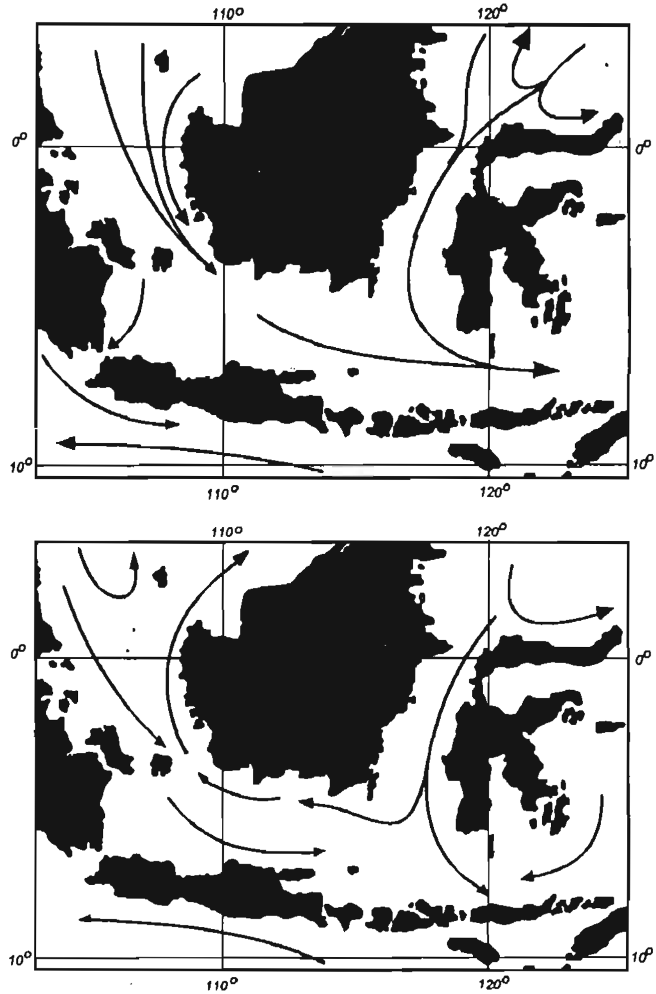
Arus permukaan di Asia Selatan pada bulan Agustus

(From Wyrtki 1961)

Figure 13

SURFACE CURRENTS IN THE JAVA SEA

ARUS PERMUKAAN DI LAUT JAWA



a: February
Pada bulan Februari

b: October
Pada bulan Oktober

(after Wyrtki, 1961)

35.5‰ waters in the South-West part of the Java Sea, we also found them along a transect toward the Karimata Strait. During the second part of the wet season, it seems that there is no hyaline separation between South-West and Karimata Strait inner layer waters.

4. PRODUCTION AND RESOURCES

As far as we know, there has never been any comprehensive study about the productivity of Indonesian marine waters. The data is scarce and was mostly collected years ago. A special mention should be made for the **Pechindon** trip which gave a complete description for the whole layer in the central Java Sea for May 1985 (Boely *et al.*,1991).

4.1 Oxygen and nutrients

During the **Pechindon** trip (May 1985) oxygen measurements have been performed from

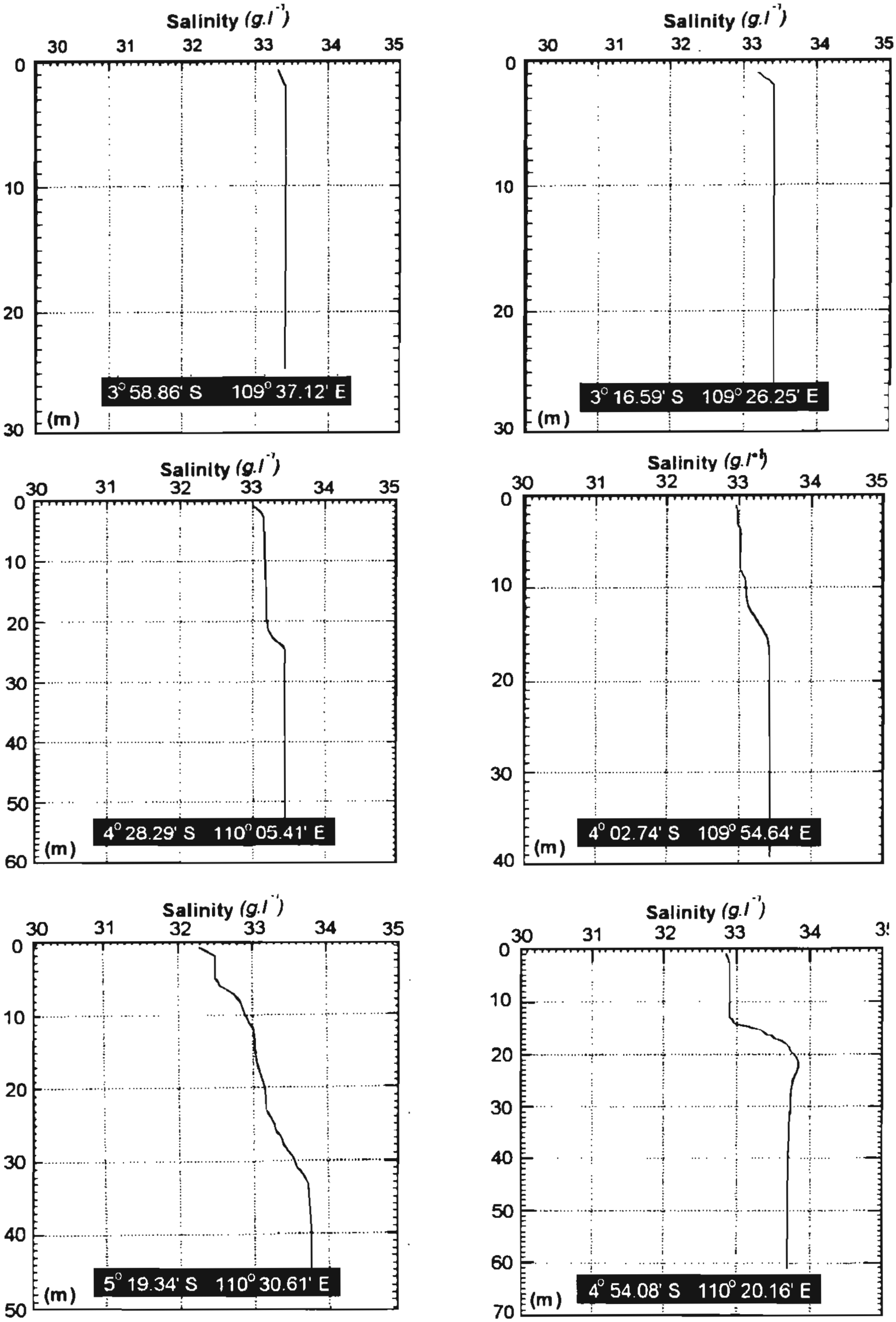


Figure 14

From the Java Sea down, toward the Karimata strait, halines profiles in April 1993

Profil salinitas bulan April 1993, dari Laut Jawa menuju Selat Karimata surface to bottom in 21 stations. They are distributed from the Karimata Strait and the South Kalimantan coast to the North Java coast in waters at least 20 m deep. All measurements gave high O_2 values: everywhere near the bottom O_2 was more than 4 ml/l and we may conclude that the whole water mass is well oxygenated (fig. 15a). at least at this time of the year. The only other measurements we found concern a few stations located from the Karimata strait to South eastern Kalimantan and performed by the **Samudera** in January 1956. All O_2 measures were high near the bottom : from 4.5 to 4.7 ml/l.

The seasonal distribution of nutrients in the Java Sea is quite unknown. In his paper about the Makassar Strait productivity, Ilahude (1978) wrote that "**the influence of the Java Sea waters in the productivity of the region is also strong [It brings] high phosphate, high nitrate and high silicate...**" We could not find the origin of such an assertion. On the other hand, during their May 1985 trip, Boely *et al.* did not find very significative concentrations of PO_4 or NO_2-NO_3, the only exception being for nitrates in transect III near the bottom (fig. 15b). Doty *et al.* conclusion (1963) seems to remain valuable : "**quantitative determination of such fertilizer salts as nitrates, phosphates and silicates should be added to the biological measurements**".

4.2 Chlorophyll a

Few papers give a first idea about a primary production : Doty *et al.* 1963 (November 1957 stations in the Malacca Strait, South China Sea and western part of the Java Sea) Soegiarto and Nontji, 1966; Nontji, 1972 (two cruises in September-October 1964 and March-April 1965 in the Java Sea); Boely *et al.* 1991 (May 1985 cruise in the Central Java Sea). According to Nontji the main values were approximately similar during the two cruises -that is to say at the end of the South-East and North-West monsoons - with 0.18 and 0.19 mg/m3 chl.a. Values higher than 0.2 mg/m3 were found along the South coast of Kalimantan during the two cruises with highest values recorded off the Barito river: 0.62 mg/m3 in March-April and 0.85 mg/m3 in September-October.

Pechindon results in June 1989 show the same range of values generally low (between 0.2 and 0.3 with two surfaces exception, towards Kalimantan again and East of the Karimunjava Islands (fig. 2a)). It is interesting to notice that intermediate waters may present a maximum toward 20 m (fig. 15c) which could be correlated with a vertical salinity gradient. On the whole, chlorophyll surface contents were 3 to 4 times lower than in the deeper layers measurements.

4.3 Primary productivity

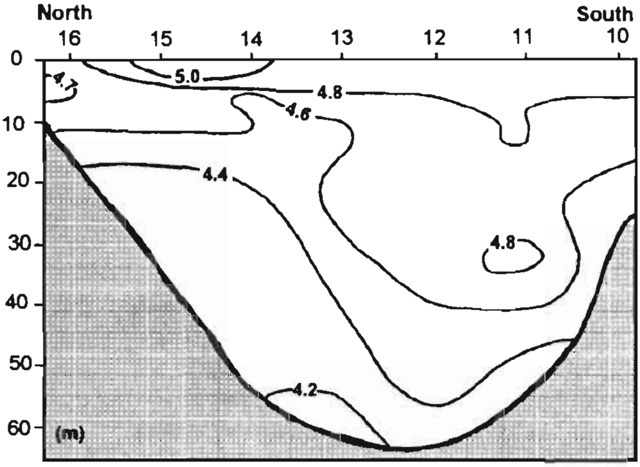
Some values of productivity are given by Doty *et al.* (1963) and Soegiarto and Nontji (1966). According to these authors the productivity measurements showed higher values during the East monsoon than during the West monsoon for open waters. In November 1957, in the western part of the Java Sea "**productiveness less than 0.2g/C/dy/m^2 characterizes the region**". The same authors gave a clear demonstration of the "**land mass effect**" for the Malacca Strait and West Kalimantan. This positive effect of run off water has also been demonstrated in the South Kalimantan Barito river.

Figure 15

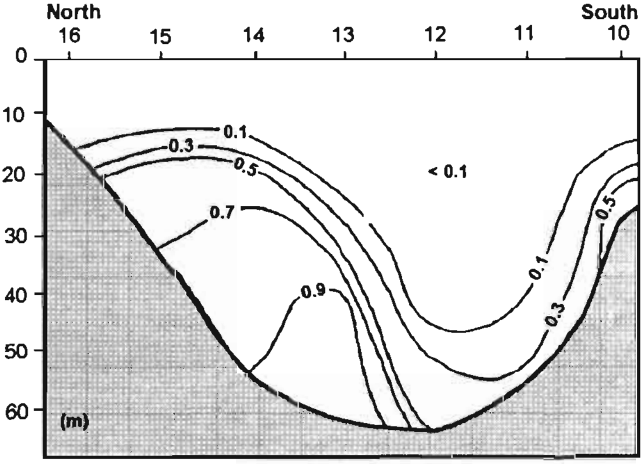
North-South cross section along 111° East

Irisan Utara Selatan pada 111° Bujur Timur

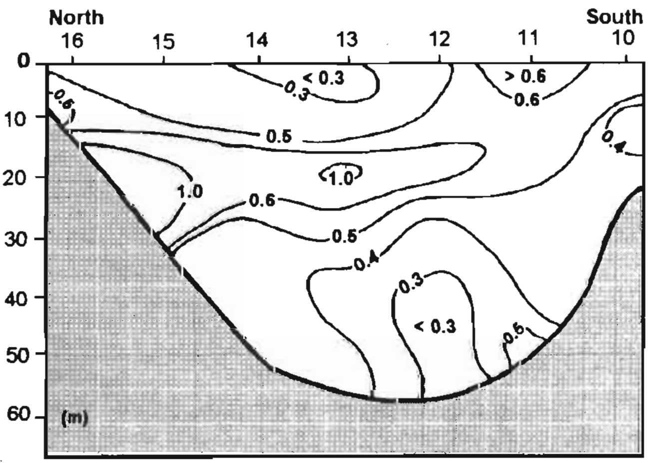
From Boely et al. 1991 : June1985, Pechindon cruise



Oxygen (ml/l)
Oksigen (ml/l)



Nitrates and Nitrites (µatg/l)
Nitrat dan Nitrit (µatg/l)



Chlorophyll a (µatg/l)
Chlorofyl a (µatg/l)

According to Nontji (1977) : **"the enrichment effect of the river was clearly seen at the three stations located near the river mouth, the further from the mouth the less the chlorophyll values were, i.e. 0.62, 0.42 and 0.23 mg/m^3. The same proved to be true for the productivity values (measurements following Doty & Oguri, 1958) i.e. 6.92, 3.01 and 1.83 mgC/hr/m^3."**

Doty *et al.* quoted Steeman-Nielsen and Aabye-Jensen (1957) who made some productivity measurements during the **Galathea** trip (1959-1952) : **"all their stations in relatively shallow waters of the Indo-Malay area yielded high rates of production, i.e. between 0.24 and 1.08 g/C/dy/m^2"**. From their results and the above quotation they concluded that **"the shallow Indonesian waters are as productive of organic waters as the most productive waters elsewhere in the tropics."**

Further investigations are needed to get a better evaluation of the primary productivity in the Java Sea in order to be more specific about this general conclusion. On the whole, even if measurements are scarce and made thirty years ago, the land mass effect is obvious and gives a noticeable enrichment during the whole year. Furthermore during the South-East monsoon there could be an enrichment through expelled waters, South-West of Sulawesi (Ilahude, 1978).

4.4 Fish Production

Fish yields in the Java Sea could give us another way to answer the question about productivity level in this shallow marine system. Obviously, when fish production (at least non harvested i.e. total catches) is high, the ecosystem productivity is high too. Marten and Polovina (1982) have carried out a very global study on fish yields from various tropical ecosystems. In comparative terms they noticed that " fin-fish catch from lakes, reservoirs, rivers, continental shelves and coral reefs fall in approximately the same range as model values in a range of 3 to 6 tons/km^{-2}/year."

For the Java Sea we used figures given from Potier and Sadhotomo who gave the main marine statistics for Indonesia and for the Java Sea in 1991 (General Directorate of Fishery). The total fish production is assumed to be 700 000 tons of which 485 000 were pelagic and 215 000 demersal fish. Related to the Java Sea area as quoted above, it means that the yields for pelagic fishery should be around 1.1 ton/km^{-2}/year and the demersal yield around 0.5 ton/km^{-2}/year.

This total average value, 1.6 ton/km^{-2}/year lays far below the estimated general range given above. Of course the method used to get this 3 to 6 ton average range could be questioned as neither MSY values nor primary productivity values seem highly reliable. Another point is the choice of area values for pelagic fishery. Lately the rate of exploitation should be taken into account. On the whole the exploitation pressure seems fairly high for coastal stocks (with some over-exploitation cases). For the offshore fisheries, demersal resources are probably under-exploited and pelagic resources fully exploited. In order to correct the previous estimation, a global sustained value could be around 2 tons/km^{-2}/year. It would mean -with all usual precautions- that the open waters productivity would not be very high. Anyway, it also means that we actually need further global studies on productivity.

CONCLUSION

From this short presentation on environmental issues it appears that in this field the acquired knowledge is noticeable but not accurate enough to answer the main questions regarding the functioning of this ecosystem.

The general climatic scheme is quite clear, at least concerning the Java Sea and the monsoons regime. Winds are seasonally reversing and so are the currents in the Java Sea : westward flow during the South-East monsoon, eastward during the North-West monsoon. Water salinity seems to be the most important parameter to be studied because it is convenient to show the evolution of water masses and because its variations have great ecological consequences.

Nevertheless it should be underlined that most hypothesis and demonstrations are relying on surface observations generally extended to the whole layer. We think that a possible gradient should be taken into account (*cf.* for example salinity section on fig. 10). Also we think that the circulation model could be more precisely described than it has been until now : dissymmetry from North to South, coastal countercurrents, specific behavior of most western water-masses.

At the time being we are not able to give a liable rough estimation of the renewal rate of water-masses and of their variations through space and seasons. The general importance of fresh waters impacts through rain at sea and outer inflows is well demonstrated. It has a major impact on salinity and on productivity through the river outputs of organic and minerals materials. It seems that Kalimantan plays a first role from that point of view, with fresh waters pouring from West and South during the North-West monsoon. With liable data it should be possible to make a quantitative estimation of fresh waters coming in the Java Sea; it supposes to search for hydrological and meteorological data around the Java Sea.

Even if we could have made a more precise description of an average hydro-climatic functioning scheme, it would not have been sufficient as inter-annual variability should also be assessed. For the time being, we are able to identify two sources of variability: regional modulations of the monsoon regime bring about variabilities on winds and sea currents, and on rainfall. From another point of view, the intrusion of oceanic waters during the South-East monsoon could be more or less directly related to El Nino southern oscillation (ENSO) in the Pacific waters. Quinn *et al.* (1978) demonstrated that unusually heavy precipitation in the coastal and western equatorial Pacific and Indonesian droughts were closely associated with El Nino type of events.

There is no need stressing on the major consequences for biology and ecology : spatial heterogeneity, vertical gradients and inter-seasonal variabilities determine productiveness, species recruitment, fish availability. It is quite obvious that management of pelagic resources refers to more accurate exploitation data but also to a better understanding of the functioning and time series data on climate and environment (cf. Freon and Saila 's contributions to this seminar).

Eventually, it remains difficult to give an evaluation of the Java Sea productivity. According to scarce and old data, we tend to think that the "specific productivity is not very high itself but is compensated by "external" inputs such as river flows and Flores Sea waters. At the present time, it is more an hypothesis than a proved demonstration.

A few conclusions may be drawn from this provisional presentation on the Java Sea environmental issues :

- There are still many interrogations but it becomes more and more obvious that the geographical frame of the Java Sea should be reconsidered for Pelagic resources and offshore fisheries. We are led to a more oriental conception of the system including seasonally the Makassar Strait waters and the East Kalimantan shelf, and excluding - maybe - the most western part, near Sumatra. This conception is confirmed through several contributions in this seminar about fishery and echo-prospecting results which should be presented in a further Projects's meeting.

- The inter-annual variability should be measured on a permanent routine basis. Whether it should be done through marine parameters measurements and/or through indirect climatic indications still has to be established. Remote sensing means could be very useful. In any case a better resources management and more prospective modeling are at stake.

- The available information on the Java Sea environment is noticeable and entire sets of data are still unused or not fully exploited : for example, the inter-annual salinity variability from 1940 to 1960; used winds and rains historic data; rivers discharge. But nevertheless, some specific programs on environment issues should be carried out in order to clearly assess the productivity and to understand the functioning of the Java Sea.

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