REVIEW OF ENVIRONMENTAL FEATURES OF THE JAVA SEA

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ABSTRACT

Old information and recent data were synthesized in order to reveal comprenhensive description of the environment feature of the Java Sea. Descriptive analysis was performed on various format of data. Physical feature of the Java Sea related to the eastern Indonesian waters and the northern region and impacts on the materials input and circulation in the coastal area. Two possible sources of variability's affecting the characteristics of the Java Sea, the first was monsoonal variability and the second was the inter annual ones. Circulation pattern generates a specific stratification of water mass that would be very important for the repartition of the pelagic fish concentration and significant factor in affecting migratory scheme of the oceanic pelagic fishes, as well as stratification of planktonic abundance and diversity.

KEYWORDS: **environment, monsoon, migratory, Java Sea**

INTRODUCTION

The Java Sea is located in the southern most of southeast Asia and bordered by three islands, Java in the south, Kalimantan (Borneo) in the north and Sumatera in the west. It is also connected to the southern South China Sea by an outlet, *i.e.* Karimata Strait, and widely opened to eastern region through Flores Sea. This condition reveals a possibility of highly influence by other ecological area, at least, the northern and eastern areas. Also, it is well known that the climate over the Java Sea is governed by monsoonal variability (Berlage, 1953; Wyrtki, 1956a; Durand & Petit, 1995).

Many factors involved in the system of the Java Sea may be deducted, but issues on the complexity of the interrelationship between many aspects, at least, need a wide range of diciplines and specific works which are beyond the scope of this study. Thus, in the context of this study, a general knowledge on the functioning of ecosystem is necessary in understanding the phenomena related to the bioecological aspects, *i.e.* population change, spatial distribution pattern, response of fishermen to disponibility of fish, as well as biological and population characters.

This study is aimed to briefly synthesize and compile the existing results of hydrographical surveys made during 1950 to 1970 decades and recent observations. This study consists of two parts: the physical and biological enviroments. Some parts have been reviewed exhaustively elsewhere (Potier & Boely, 1990; Durand & Petit, 1995). It includes an evaluation on climatic variability and its relation to the hydrographical properties and orographical feature of the terrestrial area.

MATERIALS AND METHODS

The data and information used in this study are from several source and studies documented in various format of figure and textual information, as well as from observations made during acoustic cruise of R/V Bawal Putih conducted by Pelfish Project in the years 1992 to 1995[1] and recent inhouse project in the year 2004 to 2005[2] (Figure 1). Descriptive presentations are performed in figures, charts, graphics and tables. Refigurizing descriptively the text formats are needed in order to clarify and to synthesize the information.

RESULTS AND DISCUSSION

Morphological Feature of the Java Sea

Toponomy and bathymetry

The Java Sea is part of the Sunda Shelf which extends from the Peninsula of Indochina and ends in the continental slope near the Madura Island. It is some shallow waters with average of 50 m deep and bordered by three main islands, Sumatera in the west, Java in the south and Kalimantan in the north. There are three possible connections to other ecological areas the Southern China Sea waters, Sulu, and Sulawesi Sea in the north and the eastern Indonesian archipelago waters in the east. In the north west and the northeast it is connected with Karimata Strait and Makassar Strait respectively and in the east it directly opens to Flores Sea.

Inside the Java Sea five groups of islands spread in this area, group of Bangka and Belitung in the northwest, Seribu Island off Jakarta,

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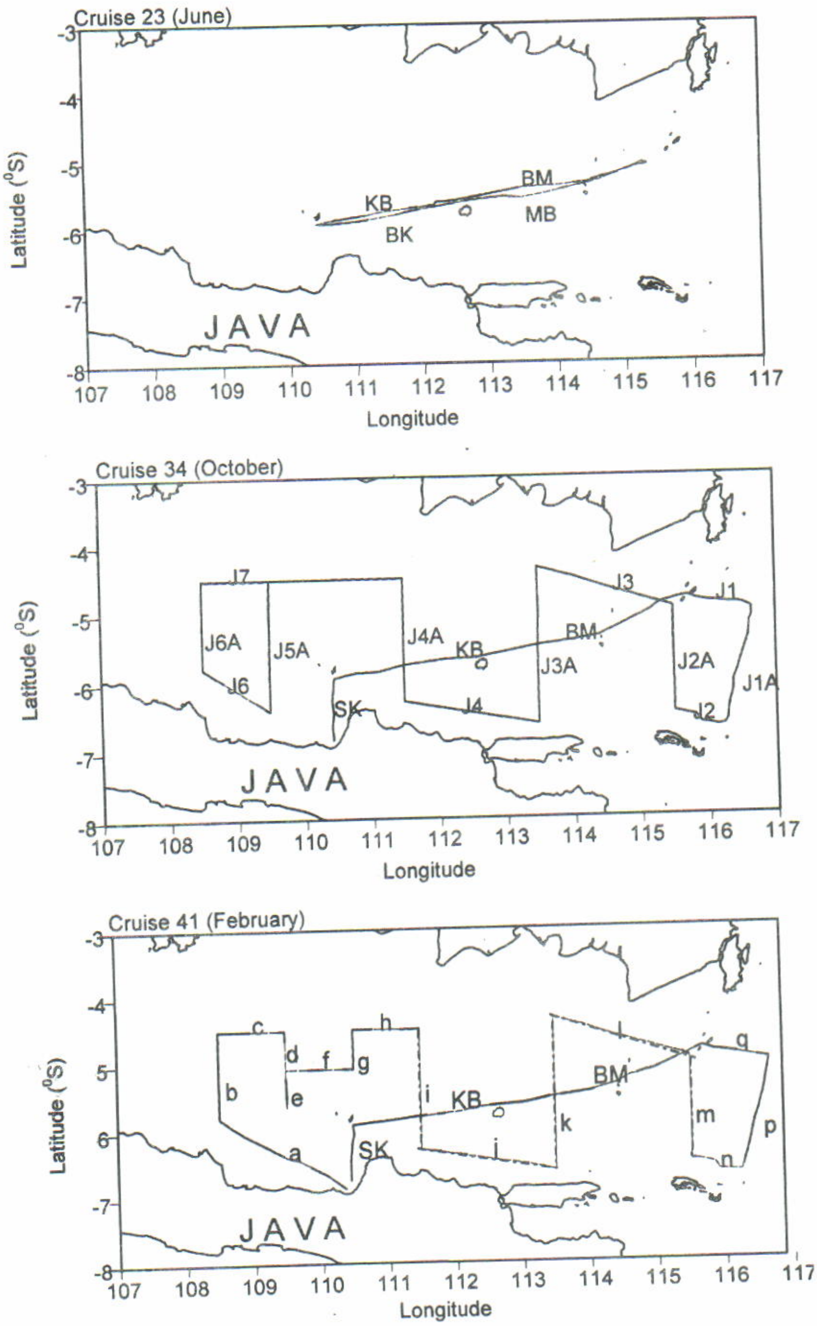
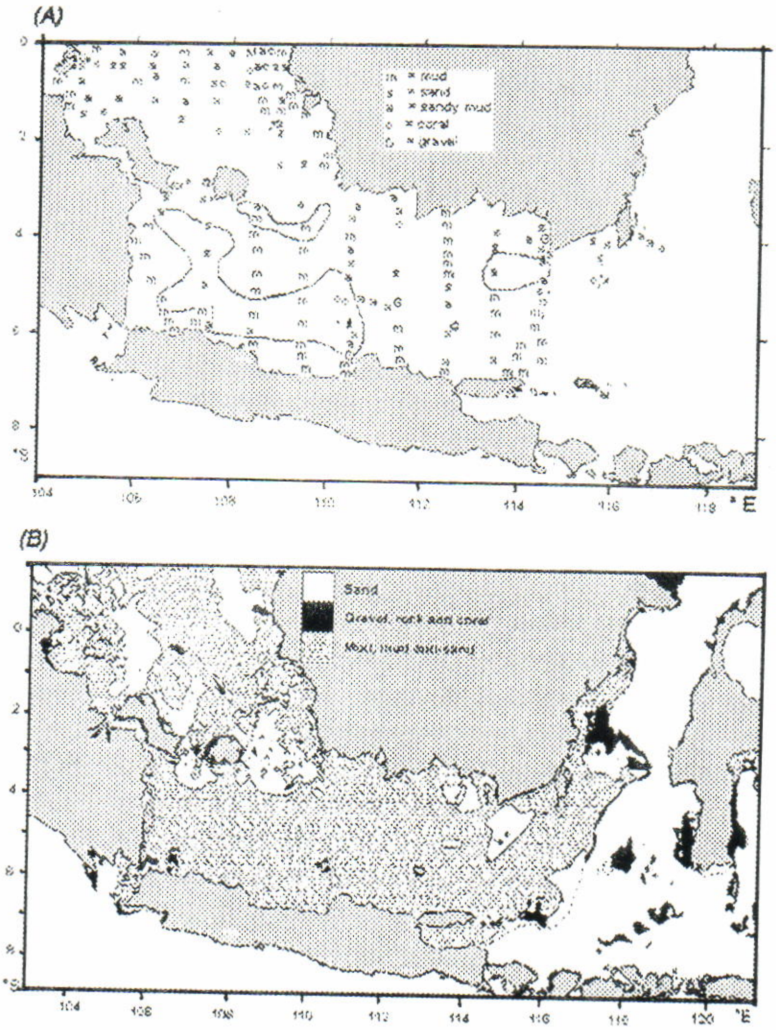


Figure 1. Selected tract used for analysis.

Karimunjawa in the middle part, Bawean-Matasiri in the east-northeast and Kangean in southeast. By considering the connecting areas, group of Natuna Island in the Southern South China Sea and Lumu-lumu Island in southern part of Makassar Strait should be taken into account.

Sedimentation and orography

The terrestrial profile and geological nature of the island surrounding the Java Sea could be regarded as a factor defining structure of bottom substrate through accumulation of sedimentation of the suspended material drifted by rivers debouching into this area along coastline of the surrounding islands. The most part of the bottom substrate and sediment of this area is constituted by silt which being formed by highly dense mud layer. In the northwestern part, the sea bed is formed with sand material mixed with coral (Figure 1). In the area near some small islands, the bottom substrate consist of a mixture of coral, gravel and



Source of data: Losse & Dwiponggo, 1977; (B) after Emery *et al.*, 1972)

Figure 2. Bottom substrat of the Java Sea ((A).

shell debris. While in some parts of non muddy substrate are frequently covered by some species of coral, giant sponge, *Poterion* (Saeger *et al.*, 1976).

Rough examination on type of bottom substrate by observing soil attached in otterboard during an extensive cruise of R/V Mutiara 4 (Saeger *et al.*, 1976; Losse & Dwiponggo, 1977; Dwiponggo & Badruddin, 1980) provides an additional information to the result of previous investigations of Emery *et al.* (1972). Type of deposited material in the sea bed indicates a possible similarity with the soil at the river basin areas. The fluvial sediment input from the land relates to the nature of geological characteristics of the superficial of catchment region (Bird, 1979).

The fluvial sediment input from the land relates to the nature of geological characteristics of the superficial of catchment region (Bird, 1979). It can be seen in Figure 2, that sand or sandy substrate tend to be exist closer to the coast of Kalimantan while in the north coast of Java, fine silt content of sediment are usually found. More detail observations made in the Java side area indicated that highly silt content (more than 75%) was found at stations located in the north coast of Java (Wilde *et al.*, 1989). It is well known that the soil type in Java is composed by gromosol and latosol in the high altitude and aluvial soil in the plane area in northern part, whilst in Kalimantan mostly by silica soil covered with peat on the top layer.

In the coastal areas surrounding the Java Sea, the phenomena of sedimentation and highly input of material from the land are apparent. Formation of river delta and natural formation of new coast line would be parallel phenomena with the deposition sediment in the sea bed. In certain delta, sedimentation process is considerably high as shown by their morphological structure, such as *multi delta* and *single finger* types of Mahakam and Solo delta, respectively. These types of delta are usually constructed by a predominance influence of river rather than other factors (Allen *et al.*, 1979). Variation of the amount of suspended sediment and other material input from land link to river debt and erosion level. However, distribution pattern of precipitation rate, topography (slope of gradient) and vegetation coverage take an important role determining this variation. In this case, high erosion process and fluvial sediment yield in Java can also be considered as the other example.

For these reasons, the influence of Solo River on the variability of coastal area in the north coast of Java is obvious. The catchment area of this river is relatively large and occupied by dense population. Also its (average) volume is considerably enermous compared with other big rivers in Java and Sumatera (Table 1) as well as a limited vegetation coverage (forested zone). Undoubtly, a consequence of short period of fresh water input and high sedimentation in the coastal area will be generated by this condition. Hoekstra *et al.* (1988) estimated that amount of sediment load from Solo River during dry season (southeast monsoon) account for only 10% of total annual input of 17 million ton. This deltaic deposition caused to an approximately of 70 m per year of actual longitudinal growth rate of new coast line.

In the southern Makassar Strait, the high dense mud layer near the delta area can be regarded as a result of deposition of suspended material input from Mahakam River and continuos direction of current (north south direction) in the strait. The circulation in the part of shallow area would create a specific circulation which spreading the suspended material coming with fresh water.

A hyphothetic local current proposed by Allen *et al.* (1979) can be used to predict distribution of enriched area. It should be noticed that the coverage of the local current would extend to southernmost of Makassar Strait. Horizontal movement of the buoyant material could be said to be more dominant than vertical transport of nutrient from the deeper part beyond the slope. Unfortunately, no large scale measurement had been made for allowing to figurise the distribution of sedimentation level over whole Java Sea.

Climatic Factor

Monsoon wind

The monsoon influences an extensive areas from east of Africa to southern part of Japan. The Java Sea, as part of its coverage areas of the influence, its climatic system is completely governed by the monsoonal climate which seasonally affects its hydrographic condition. Following Fieux (1987); the monsoon could be defined as a semi annual reversal of wind and current regime. The areas influenced by the monsoon could be expressed in term of atmospheric and oceanic parameters (Pedalabord, 1970). By this definition, the monsoon regime of wind and current over the Java Sea area could be considered as monsoonal those, where the direction of prevailing wind and current change by more than 90, *i.e.,* northwest to southeast direction during North West Monsoon and the opposite direction during Southeast Monsoon (Figure 3). As consequence of this seasonal changes, the monsoon clearly impact a periodical changes of atmospheric parameters in the Java Sea. During north west monsoon (November to February) the prevailing winds come from the northwest to the southeast with the humid air from the Indian ocean.

From June to September, during the southeast monsoon, the wind blows from the southeast bringing dry air from Australia region. The intensity

Table 1. Catchment area and volume of selected big river in Java and Sumatera (Badan Pusat Statistik, 1994)

	Catchman area (100 km²)	Volume (10^6 m^3)		Catchman area (100 km²)	Volume (10^6 m^3)
East coast of South Sumatra:			**North coast of Java**		
Batang Rokan	4.8	4.1	Cimanuk	0.5	0.5
Batang Kampar	4.0	7.6	Ciujung	1.6	1.6
Kampar Kiri	3.4	4.5	Ciwulan	0.5	1.3
Kampar Kanan	3.2	3.7	Kali Bodri	0.6	0.9
Kampar Tengah	1.7	8.0	Kali Serang	3.1	2.6
Batang Tembesi	1.5	4.0	Kali Lusi	2.6	1.2
Batang Hari	17.8	nd	Kali Lukito	0.3	1.9
Way Semangka	1.4	2.0	Kali Solo	37.0	25.2
			Kali Brantas	6.4	9.5

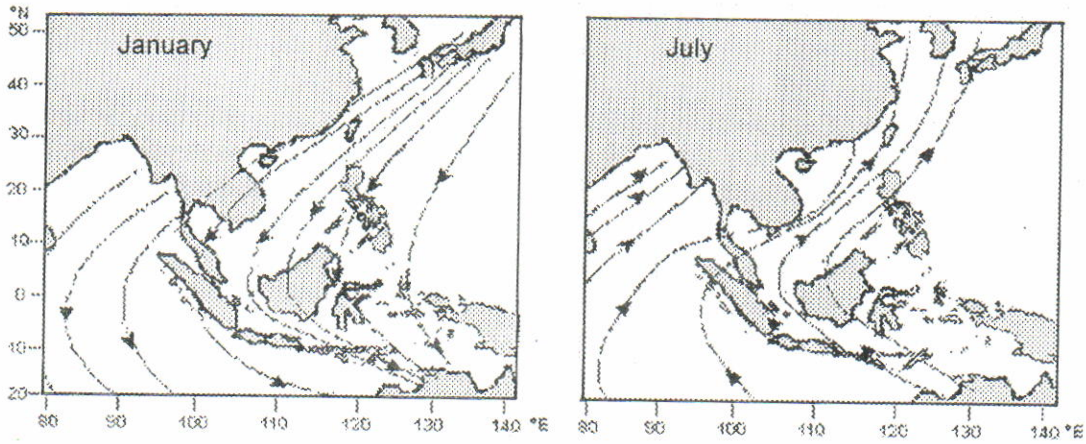


Figure 3. Monsoon wind direction during January and July (Fieux, 1987).

are more regular but the maximum wind force to be less than the previous one. Based on meteorological station in Jakarta harbour, a maximum of wind velocity was 35 knot during December to January, (Wyrtki, 1956b) but in other report, the maximum one at sea can attain 7.2 m per second in August (Wyrtki, 1957), but in other term, the worst weather condition was in December with the sea state to be around 4 to 5 of Beaufort scale as reported in the captain bridge chit record of the demersal research vessel Mutiara 4 (Losse & Dwiponggo, 1977). Owing to the frequency of occurrence of its directions, the component of east and southeast wind during southeast monsoon is greater than the west and northwest ones during opposite season (Figure 4). During intermonson (March to May and October to November), wind direction seem to be more vary as indicated by local wind blows from and to the land. It seems that local winds produced by the difference air pressure of above the sea and the land, sometime is more important than the monsoonal one. As stated by Durand & Petit (1995) that land wind can play an important role in regulating the current during inter monsoon and west monsoon. A similar figure has been demonstrated by Potier & Boely (1990) based on the record of commercial vessel ship passing this area.

Current Regime

In the Java sea, the currents are generally ruled by the monsoon and their directions tend to follow the prevailing wind which gradually change all of the year with reversal during periods of June to August and December to February. However, this cycle generates a structure of water mass and its consequences through water mass exchange with other areas. The change of salinity should be sought as an indicator of this process. These phenomena have been described (Veen, 1953; Wyrtki, 1957; 1961) and some review in conjunction with fishing system have been presented elsewhere (Potier & Boely, 1990; Durand & Petit, 1995).

In general, the wind driven currents just reflect the movement of surface or near surface water mass, but due to the depth of the Java Sea a possible vertical mixing is obvious though the coriolis effect could be ignored because of low

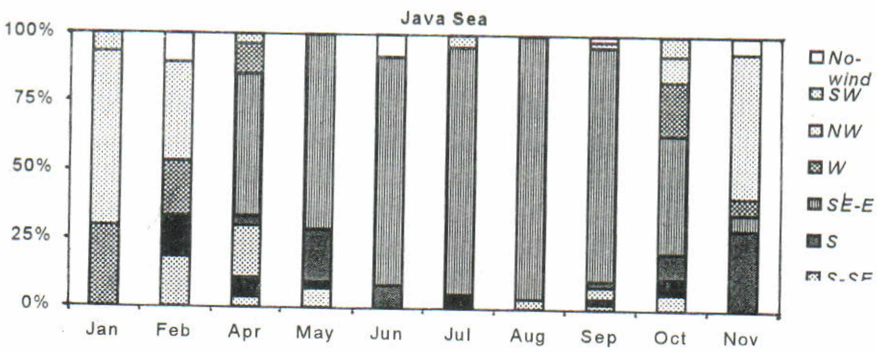


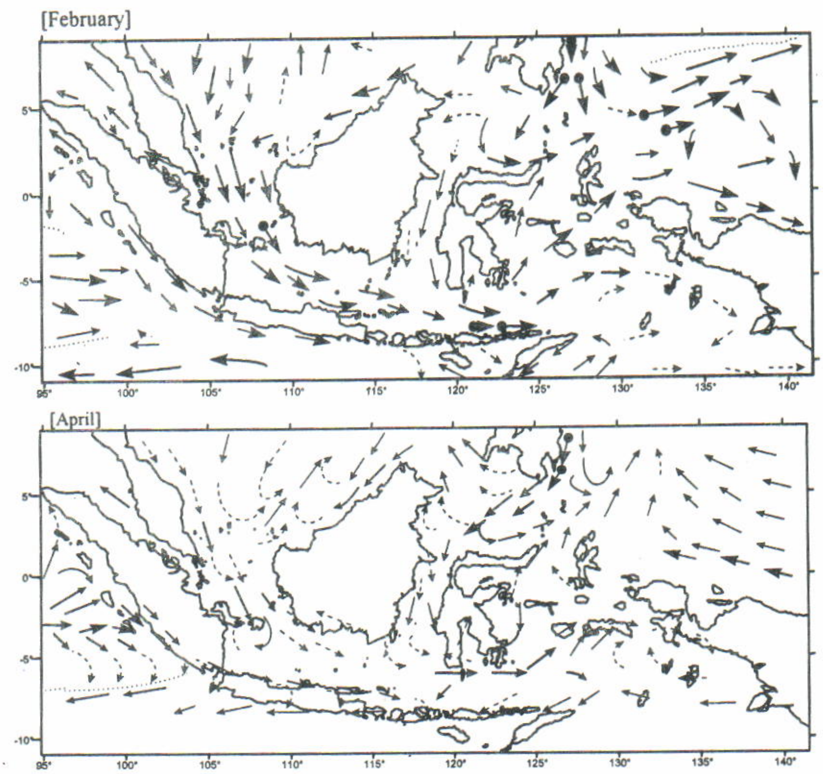
Figure 4. Composition of wind direction in the Java Sea and Southern South China Sea.
Source of data: Saeger *et al.*, 1976; Losse & Dwiponggo, 1977; Dwiponggo & Badruddin,1980

latitude position of the Java Sea. However, the horizontal currents engender a gradual shifting of water mass from eastern part during the Southeast monsoon (July to October) and from the north and west during North West monsoon (December March).

The water exchange through the Flores Sea during the Southeast monsoon and Karimata Strait during North West monsoon respectively can be regarded as important factor determining seasonal change of hydrographical characteristics of the Java Sea. Seasonal movement of the water mass will raise an ecological issue about its relation to eastern part of Indonesian archipelago and the Southern China Sea. In other side, the eastern Indonesian waters, the Banda Sea and part of the Flores Sea are well known as a gate of the throughflow between the Pacific to the Indian Ocean (Molcard *et al.*, 1995). Refer to bathymetry chart, three passage would play an important role in large scale circulation between the two oceans Lombok Strait, (between Bali and Lombok Islands), Banda Sea and Timor Sea (Timor Passage). As shown in current chart of Wyrtki (1957) (Figure 5), the currents flow from Pacific Ocean to Indian Ocean pass these passages during southeast monsoon (June to August), while during northwest monsoon the inverse movement of water mass acts in lower intensity. It can be noticed that the tendency of the throughflow would be from Pacific to Indian Ocean. So, by considering the depth of the sea bed and the occurrence others deeper passages allowing water exchange between Pacific and Indian Ocean, *i.e* through Lombok Strait, Banda, and Timor Sea, it is less possibility of direct interconnection between Java Sea and those oceans. But, due to its location, in lower scale, the Java Sea could be sought as the main passage of the water flow from and to the Flores Sea and the South China Sea. While, a connection with the Indian Ocean is probably exist through Sunda Strait in low intensity.

Refer to the results of previous works (Wytki, 1957; 1961), trend of the current direction in the Java Sea can be clearly described as in Figure 5. At the beginning of the southeast monsoon on June the current comes from the east, bringing a higher salinity waters mass from the Flores and Banda Sea as well as from the Makassar Strait, but the penetration of high salinity water does not reach yet the middle of the Java Sea (detail of explanation is presented in the next chapter). During this period, the sea front clearly showed the direction of this current (Emery *et al.*, 1972).

The resultant of current will not change until September while the strongest velocity occurs in August. In October, a weak current still enters the Java Sea from the east, with the resultant of the direction in the northern part, in the south of Kalimantan Coast, while a west current begin to enter weakly from Karimata Strait passing the



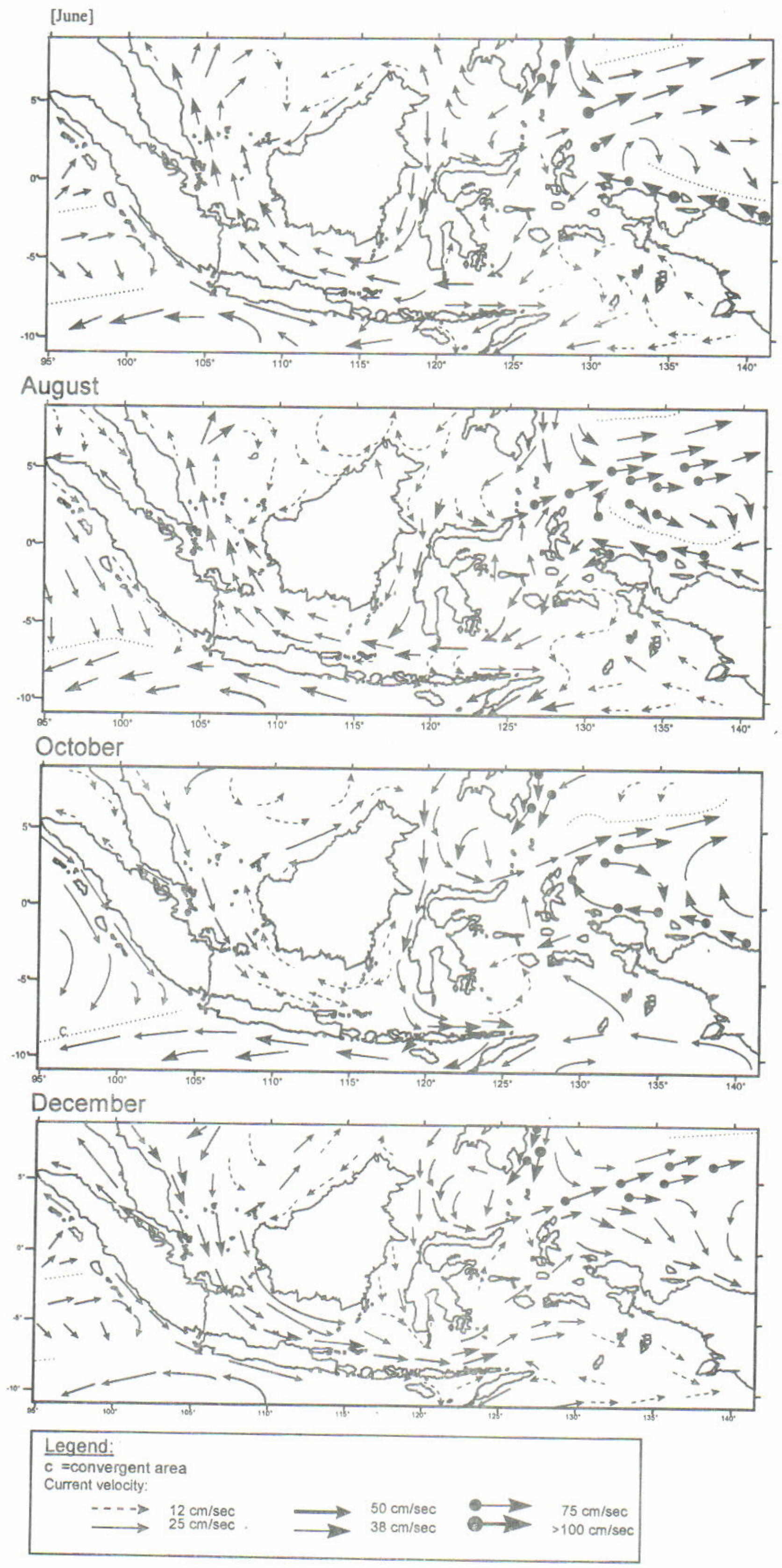


Figure 5. Surface currents around Indonesian waters (Wyrtki, 1957).

southern part of the Java Sea. During periods of inter-monsoon (October to November), 2 directions of currents exist in the Java Sea, the shifting of water mass change gradually. On December, current direction completely inverses, and this direction will be maintained until March to April. On April to May, that is under period of second inter monsoon, 2 opposite direction of current will occur as the first one. During the inter monsoon the direction of wind and current frequently change irregularly.

Rainfall

Generally, over almost part of the land surrounding the Java Sea, rainy season occurs during the North West monsoon, lasts from December to February with its peak in January, while dry season lasts from July to October during Southeast monsoon and attaining its minimum rate on August or September. The relative humidity reaches its maximum value at 89% on December and January, and the minimum one observed on August at 77%. in the mainland these atmospneric parameters behave in the same fashion.

Precipitation usually tends to follow a cycle of the wind regime and atmospheric seasonal changes. Rainfall over the sea areas usually to be assumed to have similar behaviour with those of the coastal and island areas. No direct observation have been done for sea areas, but an estimation derived from these sort of stations as conducted by Wyrtki (1956). The sea rainfall should not be sought as the main factor in desalinisation of sea water, since run off and river discharge also contribute to this process. Distribution of precipitation profile over the mainland surrounding the Java Sea would give influence on seasonal variation of dilution of the coastal water by the river discharge.

In this case, monthly fluctuation of precipitation rate in the catchment areas directly relates to the variation of river discharge debt. During the rainy season, a heavy precipitation will be immediately followed by an increase of fresh water discharge of the rivers flow from the main island. By taking Negara and Amandit River (as part of Barito River in south Kalimantan) for representing the main one, a coincidence fluctuation of the discharge with rainfall over the catchment area seem to be obvious (Table 2). However, distribution pattern of the rainfall is not same to each area. In Java, monthly fluctuation usually more vary than those in Kalimantan and Sumatera.

By referring to zonation of precipitation profile or agroclimate chart (Figure 6) (Huke, 1982), it is clear that the length of dry season in the catchment and upstream areas of big river in Java (such as Solo river) is absolutely longer than in Kalimantan and Sumatera. Also shown in Table 2, at three stations in the north coast of Java

Table 2. Average of precipitation rate of several stations in Kalimantan, Sumatera, Java, and over sea areas and river discharge of two rivers in Kalimantan

Items	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainfall rate of land stations [1] (mm)												
Banjarmasin	403	359	336	270	299	125	167	69	81	192	266	356
M. Pudak	303	243	260	224	173	153	129	90	120	189	259	296
Pontianak	270	117	301	317	314	275	216	184	379	358	468	271
Ulin	399	341	370	264	358	144	203	153	182	130	237	388
Samarinda	189	161	183	189	244	163	159	108	110	136	216	215
Pekan Baru	172	209	233	288	224	223	128	149	222	258	284	275
Jambi	233	170	228	333	167	98	88	110	145	226	221	255
Jakarta	391	258	153	124	129	72	78	58	57	76	126	286
Semarang	515	406	300	160	150	90	87	35	95	154	276	304
Surabaya	388	270	227	118	88	97	67	38	77	126	173	234
Rainfall over sea areas [3] (mm)												
Java Sea	288	219	202	166	177	127	93	58	46	96	151	257
Flores Sea	274	193	195	188	176	137	69	26	23	52	126	240
South China Sea	287	162	176	176	183	166	142	139	188	267	309	338
Discharge debt (m^3 per sec)												
Amandit river [2]	41	44	38	40	36	27	18	12	12	12	19	39
Negara river [2]	203	192	174	182	151	117	95	50	33	36	88	164

Remarks: [1] = based on monthly data of 1970 to 1993, otherwise on 1980 to 1988 (Source: Agency of Meteorology and geophysics, Jakarta)
[2] = based on monthly data of 1977 to 1987 (Source: Directorate General Water Resource and Developement-JICA, 1988)
[3] = based on an averaged from several coastal and island stations over 27 to 35 years (Wyrtki, 1956)

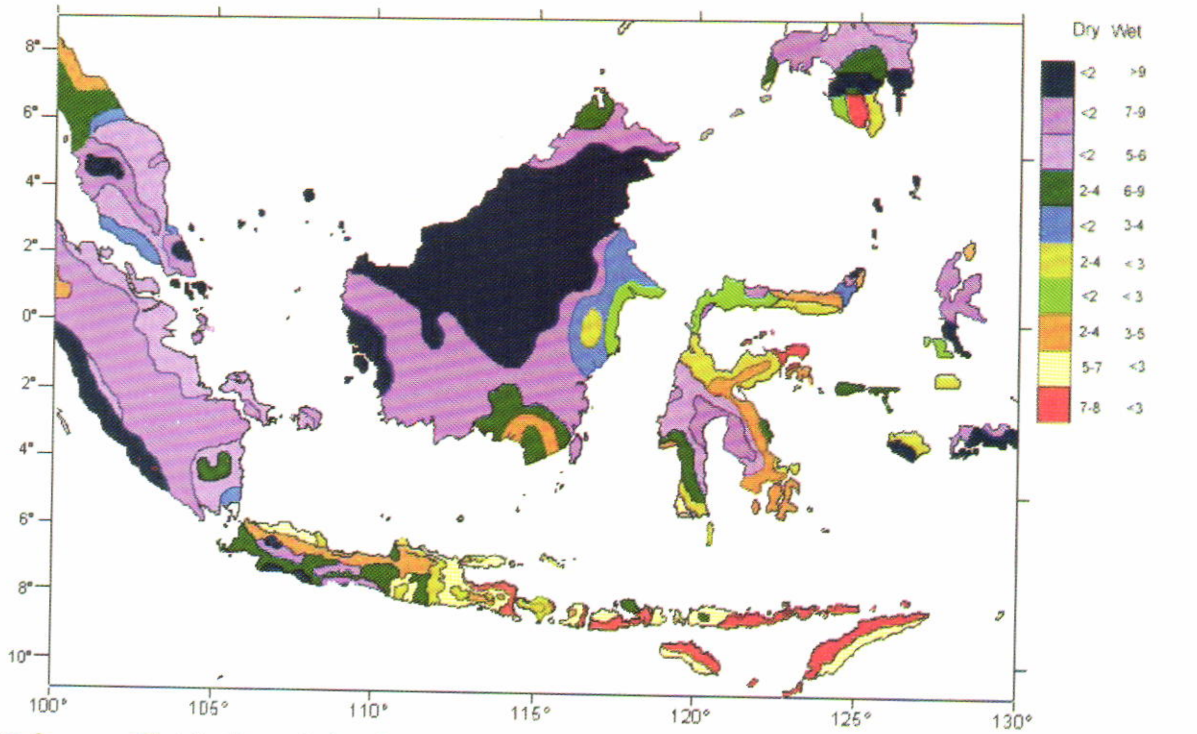


Figure 6. Distribution of duration dry and wet season as described as number of months with precipitation less than 100 mm for dry season and more than 200 mm for wet season (Huke, 1982).

(Jakarta, Semarang, and Surabaya), the length of period that the precipitation rates less than 100 mm is 4 to 5 months, while in Sumatera, Kalimantan, and South China Sea, the duration of the dry season usually less than 2 months. Hence, different seasonal variation of the precipitation over the three main lands clearly result different pattern of the debt of river discharge and intensity of dilution process in the coastal areas. The longer dry season in central and east Java and less amount of river discharge generate a different pattern of dilution along north coast of Java.

Interannual Factor

A coherent of global pattern of oceanic and atmospheric fluctuation, so called, Southern Oscillation would give an important impact on climatic variation, as well as hydrologic one. This anomaly occurs coincidentally with major change in current and temperature in the eastern equatorial Pacific, which is so called El Niño. Then, the two phenomena refer to jointly as El Niño-Southern Oscillation. The influence of El Niño-Southern Oscillation on South East Asia has not yet been comprehensively mapped (Nicholls, 1993). In term of climatic parameters, it could be shown by dislocation of rainfall in some areas. Anomalously heavy precipitation in the central and western equatorial Pacific and Indonesian drought are associated with El Niño type event. Based on 116 years of historical data, the association of Southeast monsoon droughts in Java with these events estimated to be 93%, while 78% of El Niño events can be associated with east monsoon drought (Quinn *et al.*, 1978).

In term of hydrologic parameter in the Java Sea, the impact of El Niño-Southern Oscillation, can be hypothesised as the increase of salinity as caused by a longer stay of the oceanic water penetrating this area.

In order to detect an interannual variability of the rainfall pattern in relation to global change of atmospheric fluctuation, serial data of precipitation from certain stations in Kalimantan, Java, and Sumatera are examined (Figure 7), as well as the anomaly index (southern oscillation index) expressed in different air pressure between Tahiti and Darwin (Figure 8). These figures clearly show that a low rate of precipitation at 2 stations of Kalimantan in 1983, at Jambi in 1989 as well as a high rate in 1988 to 1989 in Kalimantan can be regarded as an anomaly which associated with El Niño-Southern Oscillation. In the year 1983 the impact of a longer dry season in Kalimantan on river discharge was clearly indicated by low debt of Negara River, in the southern part of Kalimantan (Figure 9). It means that dilution process in the coastal area in whole Java Sea during that period would be lower than those of normal years. Also, high rate of precipitation in 1989 which was an unusual rain pattern in Java indicating an

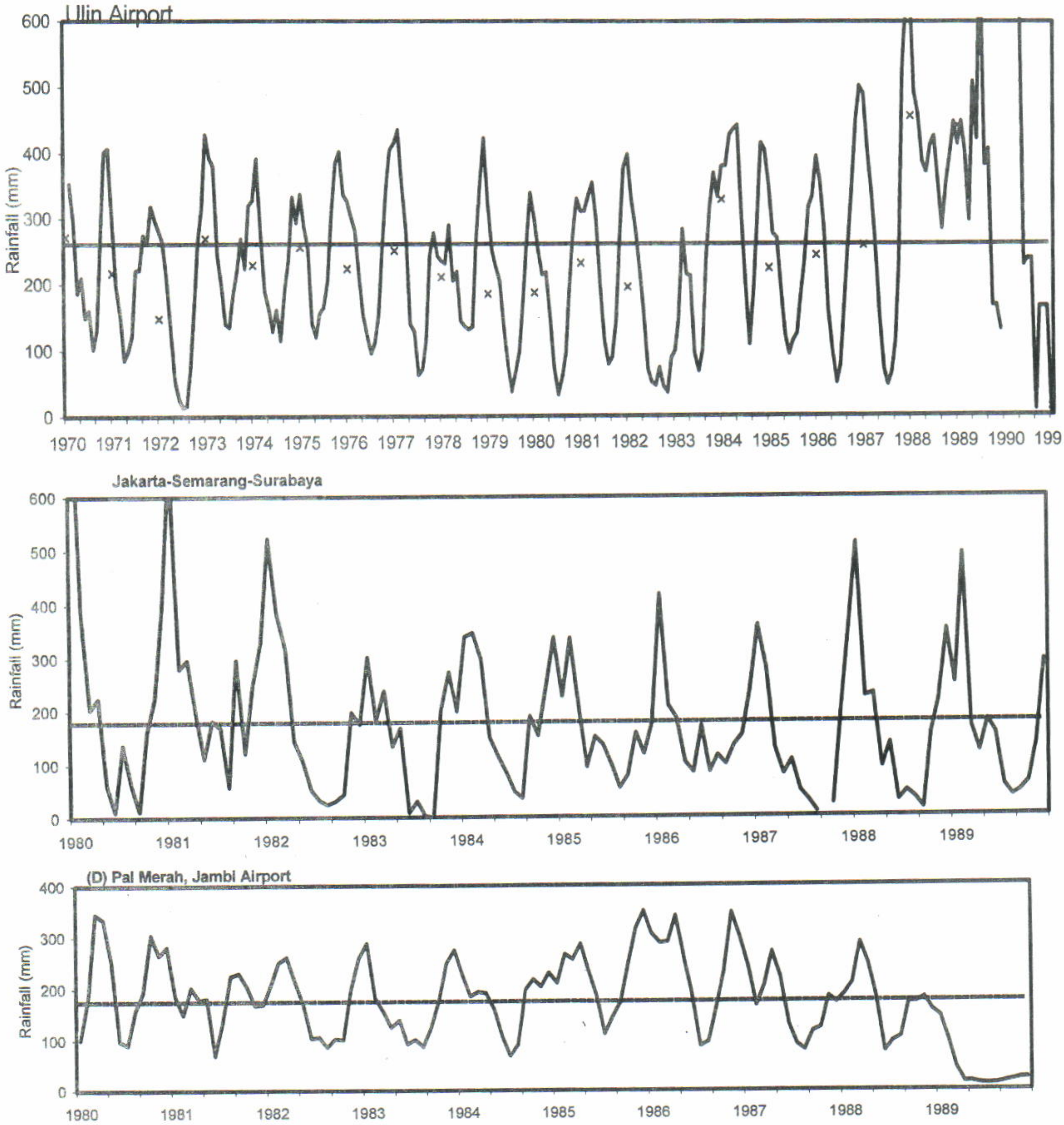


Figure 7. Evolution of monthly precipitation rate at various stations in Java, Kalimantan and Sumatra. Remarks:x's indicate yearly average
Source: Agency of Meteorology and Geophysics, BMG, Jakarta

association or indirect relation with the phenomena of El Niño type event (Quinn *et al.*, 1978; Karmini *et al.*, 1995). At the same period, in Jambi, the rainfall showed a different tendency, the precipitation rate was considerably very low. In north coast of Java, as represented by the average of three stations in Jakarta, Semarang and Surabaya, a high precipitation rate in 1981 to 1982 tended to be more obvious than in the periods of 1988 to 1989, and low rate in 1983 seemed to be a normal rather than an extreme value in drought period. These patterns do not give a similar figure for the three island, but trend of the rainfall oscillation in Java and Kalimantan potentially behave similar fashion.

Hydrology

Salinity and horizontal circulation

The surface current regime as described by Wyrtki (1957; 1961) would reveal many possibilities of a mixing process and the influences of other waters areas on the characteristics of the

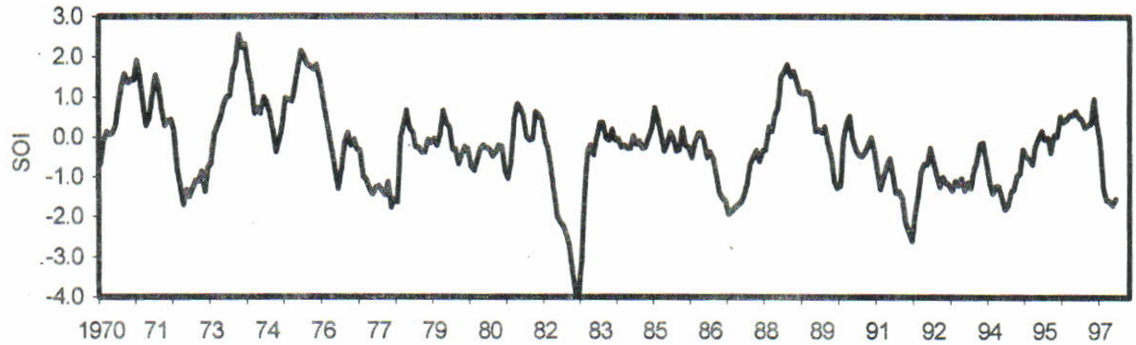


Figure 8. Southern Oscillation Index observed during last three decades.
Source: http://www.nodc.NOA.gov

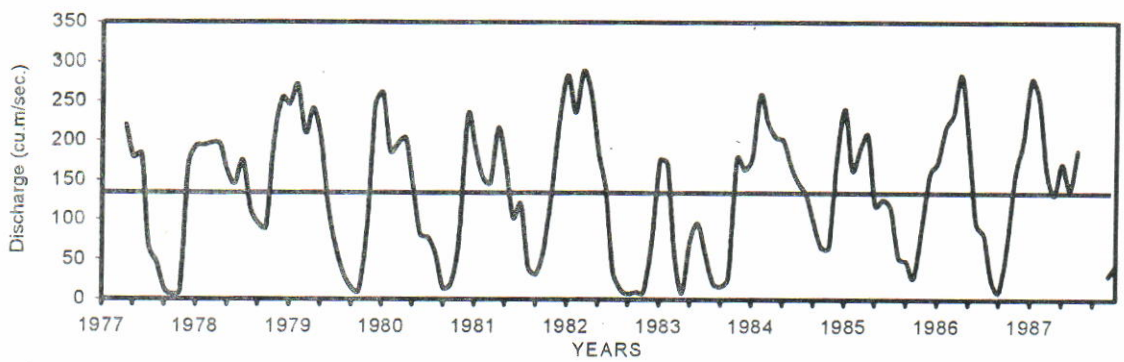


Figure 9. Evolution of river discharge of Negara River (a tributary of Barito River) South Kalimantan. Source: Dir. Gen. Water Resources Dev.-JICA, 1988

Java Sea waters. At least 2 sources of sea water masses entering the Java Sea can be defined: one is the origin of Southern China Sea by passing Karimata Strait and another one coming from Pacific through Flores Sea and Makassar Strait. Also, desalinisation following an input of high debt of fresh water discharge creates another type of a seasonal mixing process in the near coastal areas. These water masses exchange and circulation are mostly governed by monsoonal system exerting through the seasonal change of atmospheric and current regimes.

Wyrtki (1956) classified the water circulating in the Java Sea into three distinguishable types. The first one is the oceanic water with salinity more than 34‰. The second one is mixed water with its salinity range 32 to 34‰ and contributing more than 60% of the total water mass circulating in this area. It originally comes from Southern part of China Sea and mixed with fresh water inside the Java Sea. And the third, is the coastal water with salinity to be less than 32‰. It has the same origin as the mixed type but it has undergone desalinisation along the coast of east Sumatera and Kalimantan during the passage to the Java Sea. Another type would be river water with salinity to be less than 30‰.

Until now, the knowledge of 2 dimensional distribution of the mixed water is unclear, and there is no fixed border horizontally defining the type of the water. In this chapter, general explanations are given and based on the progression of the more dominant water penetrating the other type of water detected from the movement of certain arbitrary isohaline, *i.e.* 32 and 34‰ isohaline for the type of coastal and of oceanic water respectively. Owing to the previous works (Wyrtki, 1956; 1961; US Navy, 1987), charts of surface salinity were redrawn with trivial modification and without changing general pattern. In this case, periodically shifting of isohaline characterising the water type origin are used to demonstrate the changes of surface salinity in relation with the water exchange and the mixing process (Figure 10).

During the Southeast monsoon, the prevailing wind and current come from the east and at the same time, the oceanic water enters the Java Sea and gradually pushes the lower salinity water to the west. On June, at beginning of this season, taking place in the eastern part of the Java Sea, the oceanic water starts to move to the west northwest direction and begin to push the lower saline water to the west. This type of water has not arrived yet

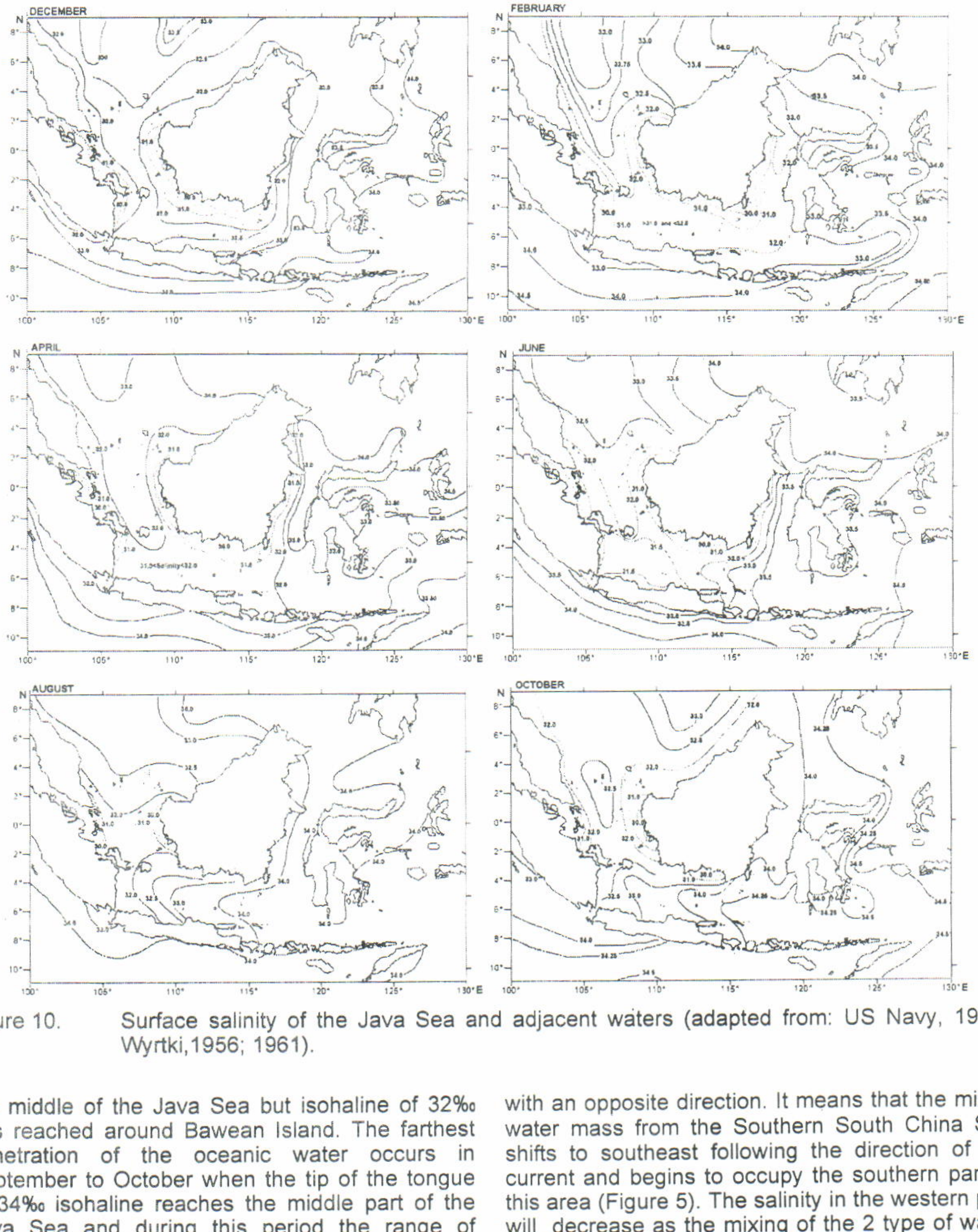


Figure 10. Surface salinity of the Java Sea and adjacent waters (adapted from: US Navy, 1987; Wyrtki,1956; 1961).

the middle of the Java Sea but isohaline of 32‰ has reached around Bawean Island. The farthest penetration of the oceanic water occurs in September to October when the tip of the tongue of 34‰ isohaline reaches the middle part of the Java Sea and during this period the range of observed salinity's values to be 32.5 to 34.25‰. It takes approximately 1 or 2 months of lack time between the peak of southeast monsoon wind in August and periods for reaching the western part.

On the contrary, at the end of Southeast monsoon on October to November, the direction of the east current tends to bend northward while in the southern part a weak current begins to flow with an opposite direction. It means that the mixed water mass from the Southern South China Sea shifts to southeast following the direction of the current and begins to occupy the southern part of this area (Figure 5). The salinity in the western part will decrease as the mixing of the 2 type of water undergoing. On December, this process will be more intensive. A stronger current bringing the water mass from the northern region starts to replace the oceanic water occupying from the previous season. In this period, salinity's values in the middle part of the Java Sea are in the range of 32.0 to 32.5‰ and tend to be lower in February to March (31.0 to 32.0‰) with the minimum values observed is located in the western part.

In term of west east axis and periodical scale, a progression of the surface salinity has clearly shown a general change of the salinity. A more detail salinity contour in the middle area may be figurised using intensive observations made during the cruise of R/V. Bawal Putih in October 1993, February 1994, and Sepetember to December 2005 (Figure 11). As shown in the figure, during October cruise, the water circulation would create a specific water mixing beginning from the middle of the Java sea, off the north coast of central Java. On October, a current flows weakly from northwest region (*i.e.* Southern South Cina Sea) then turn to the east direction as its velocity slowing down as far as Bawean Island. However, this current is considerably very weak but it can slightly push part of water mass body in longitudinal direction, at the same time, fresh water discharge from land gives additional contribution to lower the salinity in the coastal area of the southern part. However, stronger easterly current is still flowing from eastern region in middle part of the Java Sea as shown in the Figure 5. This scheme would continue until the inter monsoon period then reverse again with reentering the oceanic water to this area during the Southeast monsoon period, from June to October.

Vertical Circulation

In fact, there is few information on the vertical shape of salinity profile in the Java Sea. The most detailed observation of the previous investigations concerned with limited area, *e.g.* the cruise of R/V Samudera in the south coast of Kalimantan as reported in the Oceanographical List attached in journal of the Marine Research in Indonesia (Soeriaatmadja, 1956; Sjarif, 1959), and the cruise of R/V Coriolis during Pechindon trip in the middle part of the Java Sea in 1985 (Boely *et al.*, 1986). An attempt to expose a preliminary result of the cruise of R/V Bawal Putih in the larger scale area has been well documented (Durand & Petit, 1995). In order to allow a comparison between sections, several tracks of salinity observation stations are arbitrarily redefined (Figure 11). Reanalysis of the same data of the cruise (*i.e.* cruise in October 1993, in February 1994 and September to December 2005) are presented in Figure 12 to 14.

In October, vertical mixing in some part of the Java Sea are evident in certain level of depth with different fashion. In the area off south coast of Kalimantan vertical mixing is a typical of dilution process which gradually taking place near the coast area the lower saline water (less than 32‰) tend to occupy near surface layer until 25 m deep, especially in the areas between 115 to 116 E and 109 to 112, whilst in the area off north coast of Java, the vertical mixing seem to be more intensive than off south of Kalimantan, as well as in horizontal direction. The salinity profile as depicted in Figure 12 in the south section, are attributed to the outcome of 2 factors, the invasion of southeastgoing current from the northwestern area pushing weakly the most stagnant oceanic water and the contribution of fresh water discharge.

In February, stratification of the vertical water layer could be said as an opposite of the first one. The strata of vertical layer are clearer and more significant in the middle and north sections. Some fresh water mass originating from river discharge in the south of Kalimantan greatly impact a vertical change of salinity in the north section. While in the south section in the eastern part of the Java Sea, the existing of lower salinity in the near surface layer maybe caused by same process. In the southwest-northeast direction, the horizontal salinity gradient is more important than the vertical one. Nevertheless, the saline water mass tends to occupies the lowest depth layer in the south and middle areas. It means that the oceanic water mass still occupying the Java Sea at least, from the near bottom layer in the longitude 109 to nearer surface as it approach the Flores Sea as confirmed by salinity profile of F3 and F6 selected stations (Figure 13).

Another possibility is the occurrence of a sub current from the east while the surface one being weakened in October. This under water current will be more important in the south section on February as shown by the thickness of the layer (Figure 14). The horizontal salinity contours drawn for 2 to 10 m and 20 to 30 m deep layers respectively in February and October (Figure 15) do not significantly illustrate a clear vertival stratification, even though the tendency of occurrence of higher salinity in the deeper layer in eastern part is apparent. Unfortunately, there is no complete information or observation made for confirming the phenomena of underwater circulation and water mixing in the inner layer of the Java Sea. It means that the oceanic water mass still occupying the Java Sea at least, from the near bottom layer in the longitude 109°C to nearer surface as it approach the Flores Sea as confirmed by salinity profile of F3 and F6 selected stations (Figure 13). Another possibility is the occurrence of a sub current from the east while the surface one being weakened in October. This under water current will be more important in the south section on February as shown by the thickness of the layer (Figure 14).

Temperature

As other tropical waters, the fluctuation of the surface or near surface temperature are relatively very small. Refer to the previous investigation and

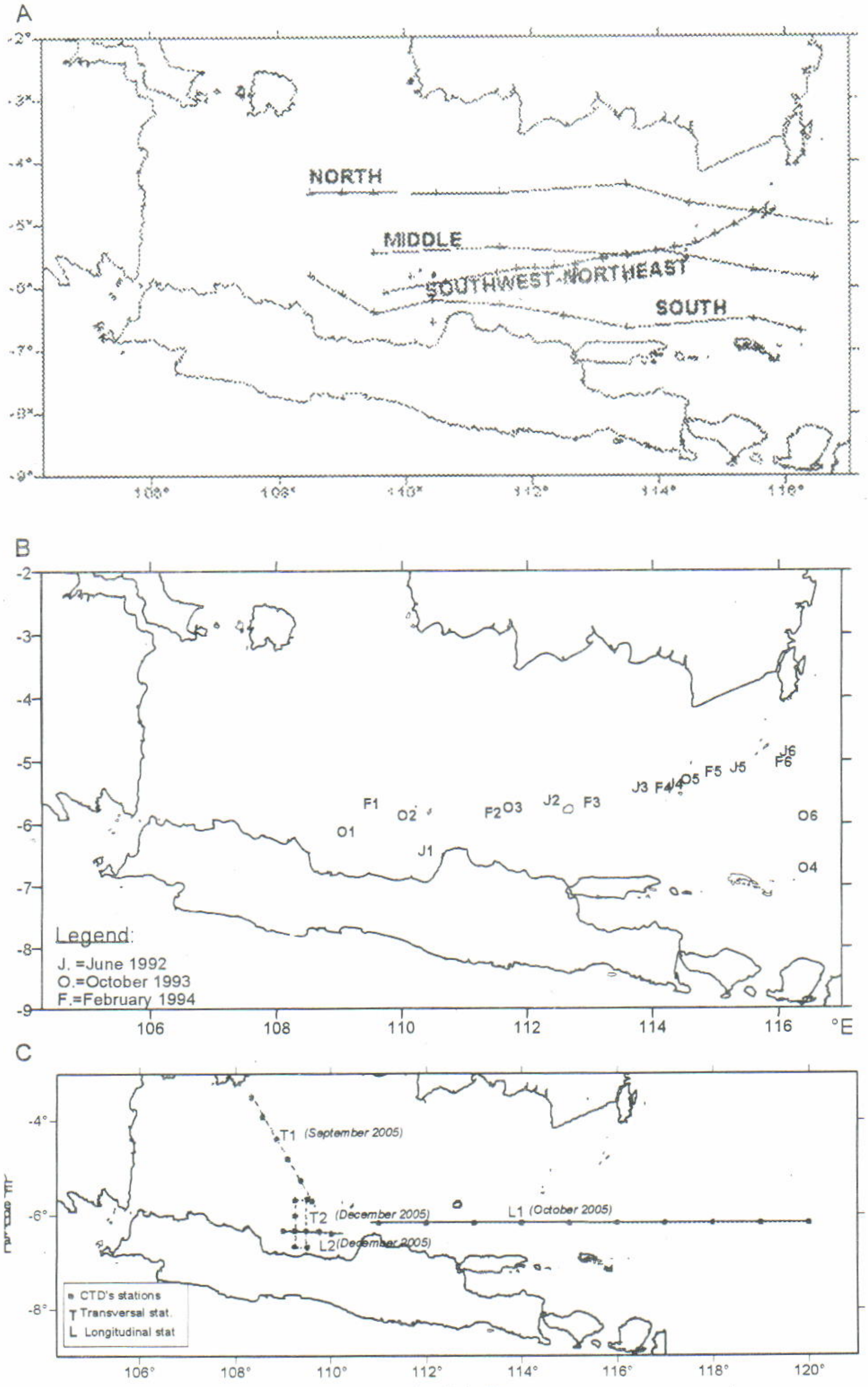


Figure 11. Position of selected CTD's stations used for defining sections zones of Figure 14.

reports (Saeger *et al.*, 1976; Wyrtki, 1957) the differences between the maximum and minimum values in the Java Sea are less than 2°C with the average value in the range of 27 to 29°C.

Horizontal distribution of surface temperature are usually attributed to the seasonal phenomena. In general, the influence of rain fall on the temperature of the near coast line waters would be significant as it was noted by Durand & Petit (1995), while in the larger area, the gradient of the temperature are caused by the different origin of water mass which seasonally invades the Java Sea. As illustrated in the temperature contour

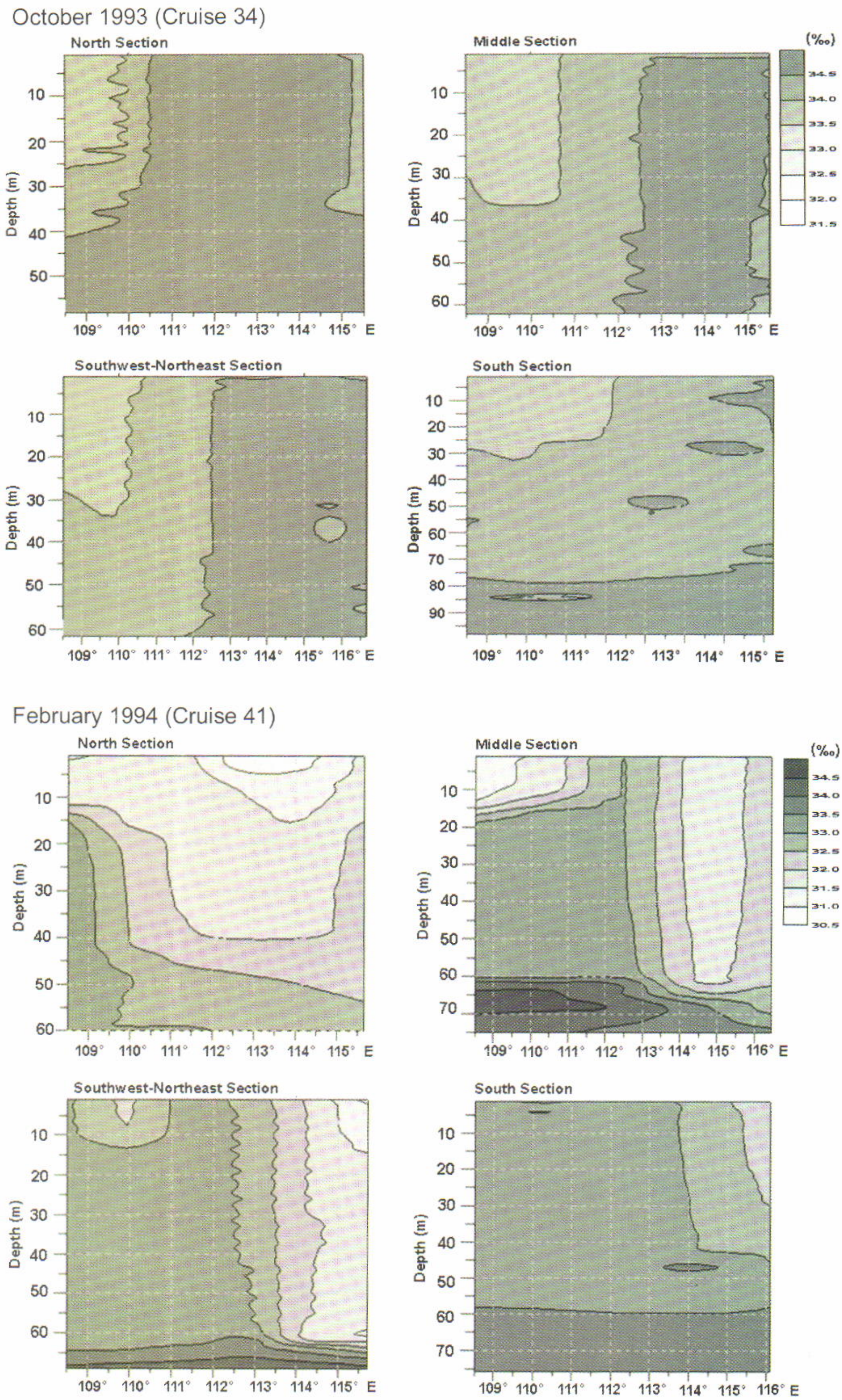


Figure 12. Salinity profile in certain sections during Cruises of R/V Bawal Putih in February 1994 and October 1993.

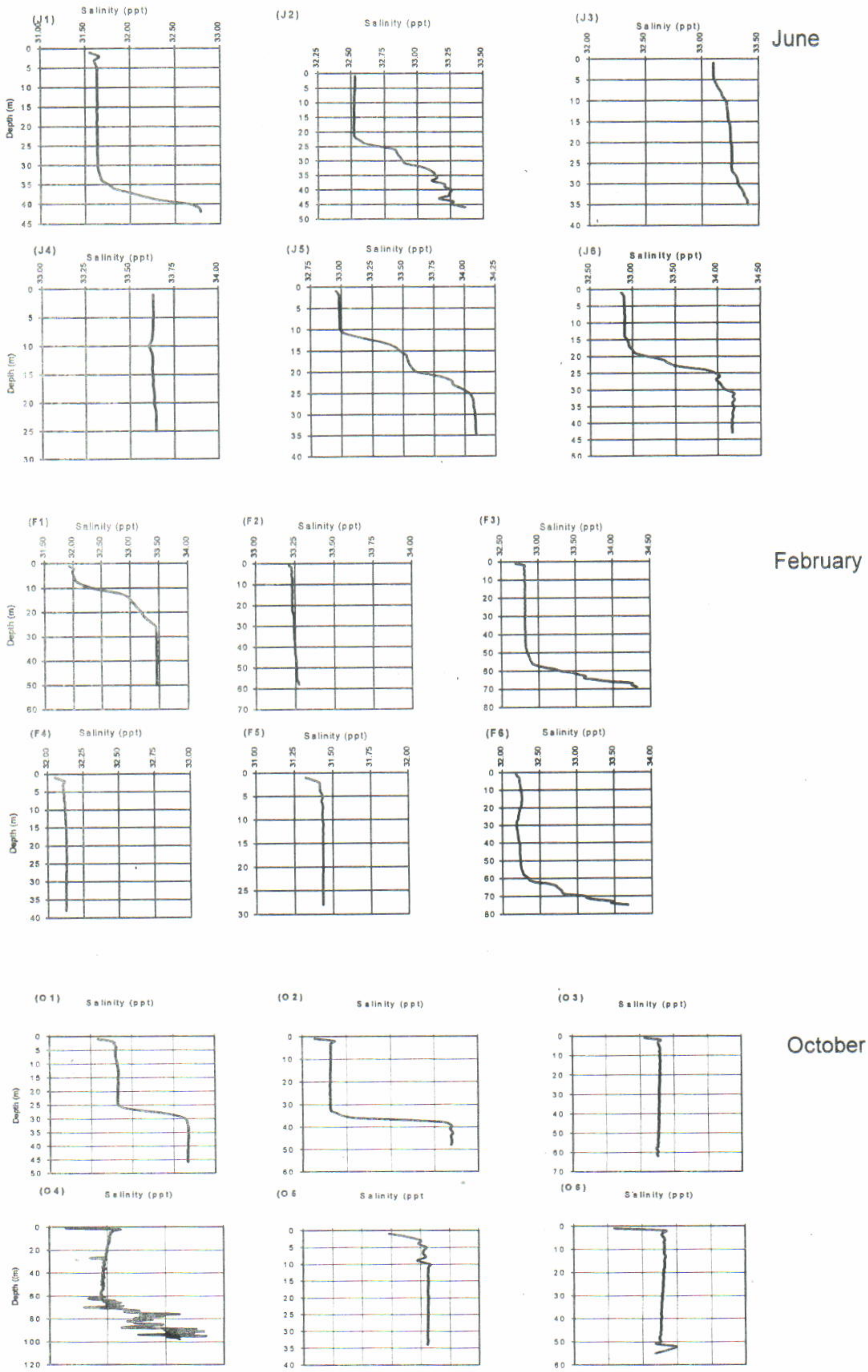


Figure 13. Salinity by depth of selected stations.

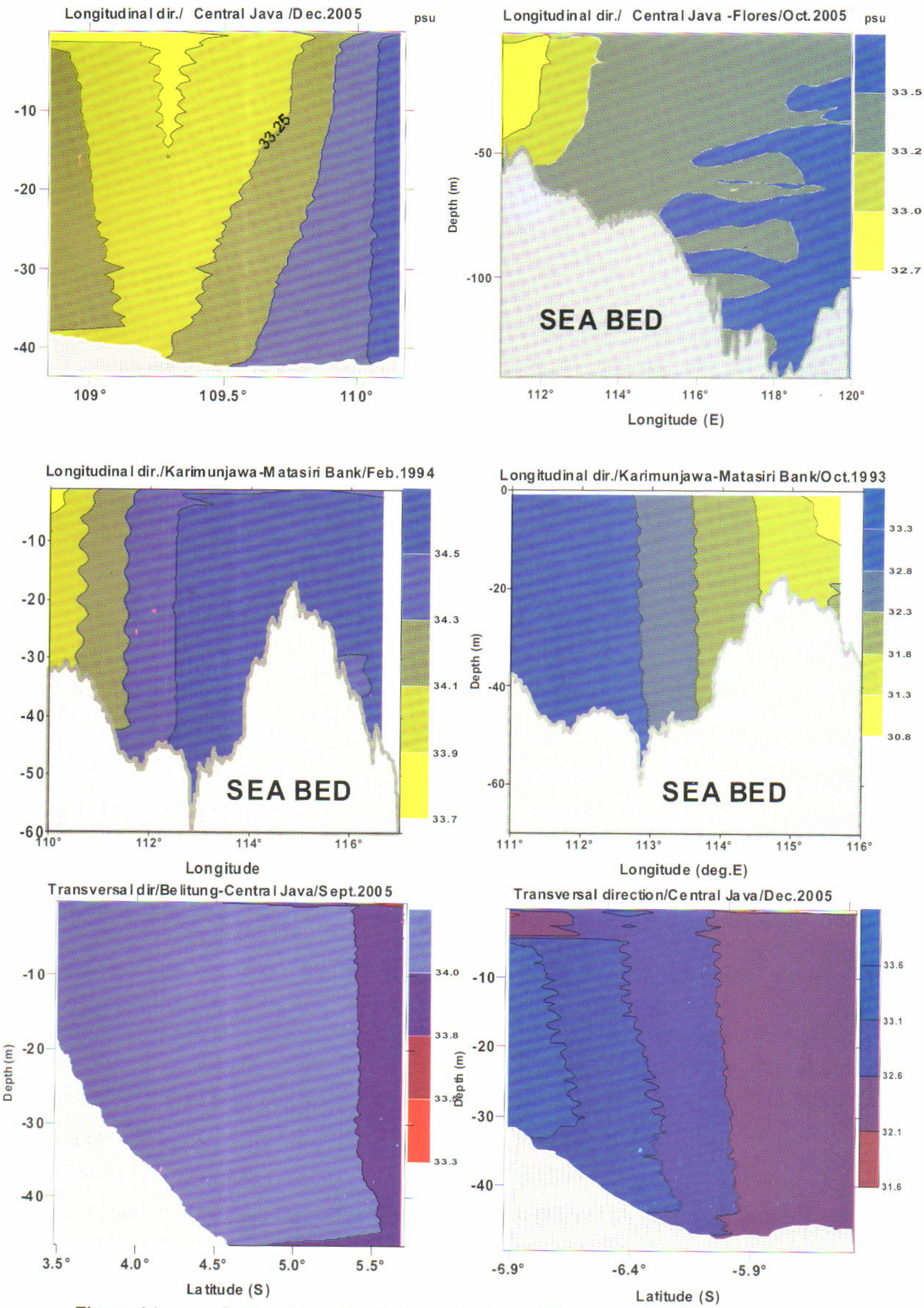


Figure 14. Comparison of salinity profile from differerent periods of observations.

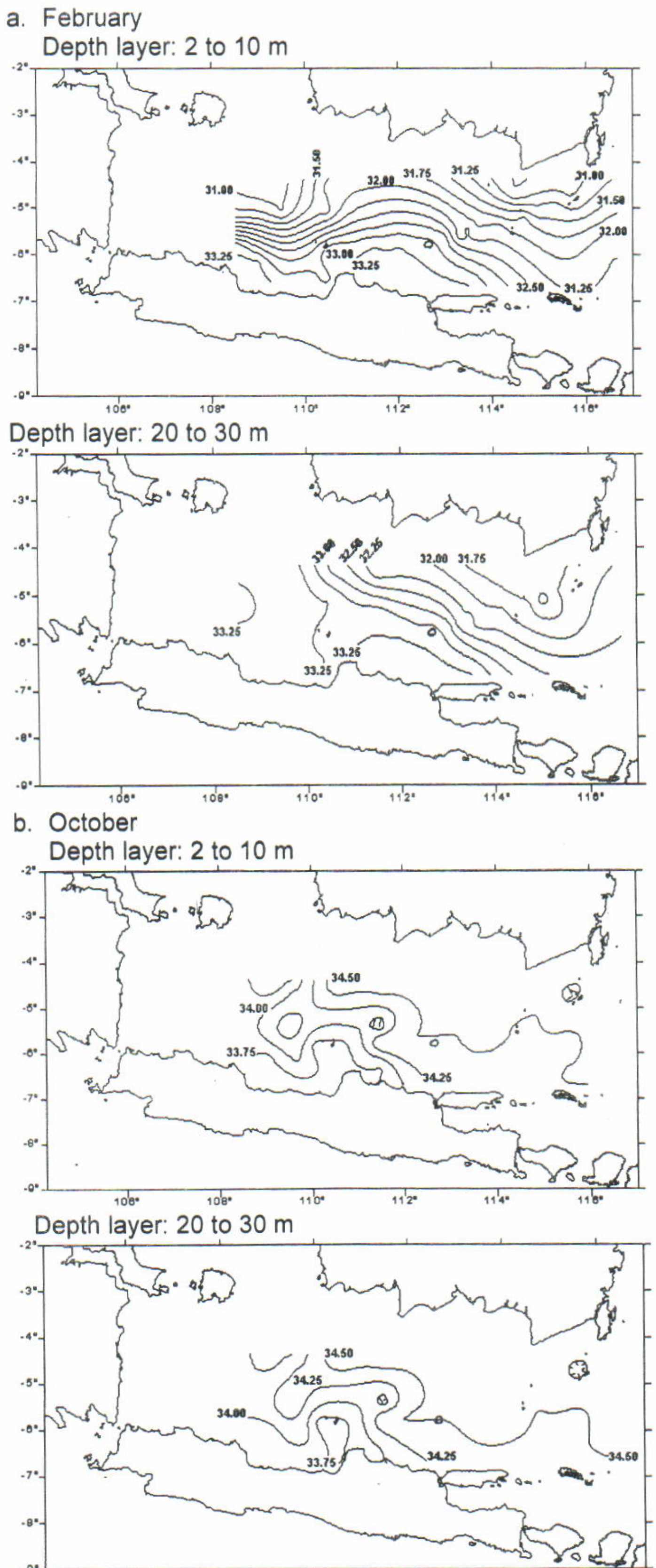


Figure 15. Distribution of isohaline in various layers.

drawn from the observations made during October and February cruises, a slight gradient were observed in southern and northern legs of the areas covered (Figure 16).

During the northwest monsoon (February), the highest temperature tends to be found in the northeast, on the contrary this gradient was reversed during the Southeast monsoon as it observed on October. Refer to the previous explanations these gradients should be attributed to the invasion of west going and east going currents. In this case, the higher salinity's water coming with east current from Flores Sea during the Southeast monsoon has a slightly lower temperature compared to lower salinity's water mass from the northern and southern parts.

The higher temperature of the coastal water mass can be sought as an outcome of a mixing with the fresh water. Hence, the fresh water runoff and disharge must be warmer than those of sea water. A comparison between temperature gradient of surface and 20 to 30 m deep layer do not give any difference, although the deeper layer having a little bit lower figure.

Turbidity

Generally, turbidity or transparancy relates to concentration of solid .debris content, buoyant particles or suspended and density of microorganism in the sea water. In ecological sense, the turbidity of sea water would be more important for pelagic fishes than demersal one. Unfortunately, no relevant information concerning to pelagic species had been published.

An attempt to figurise the distribution of transparancy of the coastal areas of the Java Sea is presented here, using the sechi disk reading data made during the cruises of R/V Mutiara 4 in the years 1978 to 1979 as listed in the report of Beck & Sudrajat (1979); Dwiponggo & Badruddin (1980). Tranparancy measurements were done by observing the minimum depth of invisible of 30 cm diameter of white disk shinked in the water. As shown in Figure 17, the tendency of transparancy in the coastal areas seems to be seasonal and their gradients tend to follow the isodepth or be parallel with coast line, as shown by the pattern of sechi disk contour line. In the Southern South China Sea, on July, the water was relatively clearer than those of south coast of Kalimantan and east coast of Sumatera during period of July to September and July respectively. In the north coast of Java, during the peak of northwest monsoon (January to February), the water was turbid, and an be regarded as being influenced by high suspended sediment load transported by river discharge. While in the offshore area, between Madura Island and Kalimantan, and off Jakarta, the water was clearer than those of coastal areas.

The water transparancy in this sub areas would attain the maximum values on October. Based on the pattern of tranparancy contour lines, there are three possible factors controlling the transparancy in the Java Sea. The first, are deposite, suspended, and buoyant materials brought by river discharge. The second one would be the depth and current. The current passing shallow area would be able to generate a turbulence in the near bottom layer and raise the deposite material in the sea bed. As mentioned above, the clear water in Southern South China Sea would be caused by low speed northwesterly current during the beginning of Southeast monsoon. The third one, is water mixing with clearer water water mass coming from Indian Ocean and Flores Sea.

The optimistic values given by him showed that the nitrate concentration in the surface layer were estimated to be in the range of 0.2 to 0.6 µgA/l with the maximum value to be 3.5 µgA/l in the near coast line of Kalimantan (Ilahude ,1979). These values are considerable high comparing with the values observed in the southern part of Makassar strait waters as reported by same author (Ilahude, 1978). But, during the cruise of Pechindon in May 1985 (Boely *et al.*, 1986) never found any significant concentration of those nutrient.

Primary Productivity

An extensive survey had been made during east monsoon (September to October 1964) and Intermonsoon (March to April 1965) covering the Java Sea, Bali and Sunda Strait, and Indian Ocean. The results gave an indication of a high rate of surface productivity in the nearer stations to the coastal area and the island. The highest figure of all areas was 39.11 mg $C.hour^{-1}.m^{-3}$, located off the estuarine area of Barito River. The average value was around half of the maximum one, and the minimum was 0.05 mg $C.hour^{-1}.m^{-3}$ (Soegiarto & Nontji, 1966). These results were slightly higher than those of Doty *et al.* (1963). It could be noticed that no significantly different between the values of surface productivity of the near shoreline area of the Java Sea and Indian Ocean. A tendency of higher rate of production from western to the eastern part of the Java Sea was obvious as well as of those of the location being closer to the shore. From south of Karimunjawa Island the figure tended to increase as the stations moving eastward. Also, the surface productivity of the Java Sea in southeast monsoon is higher than other season (Figure 19).

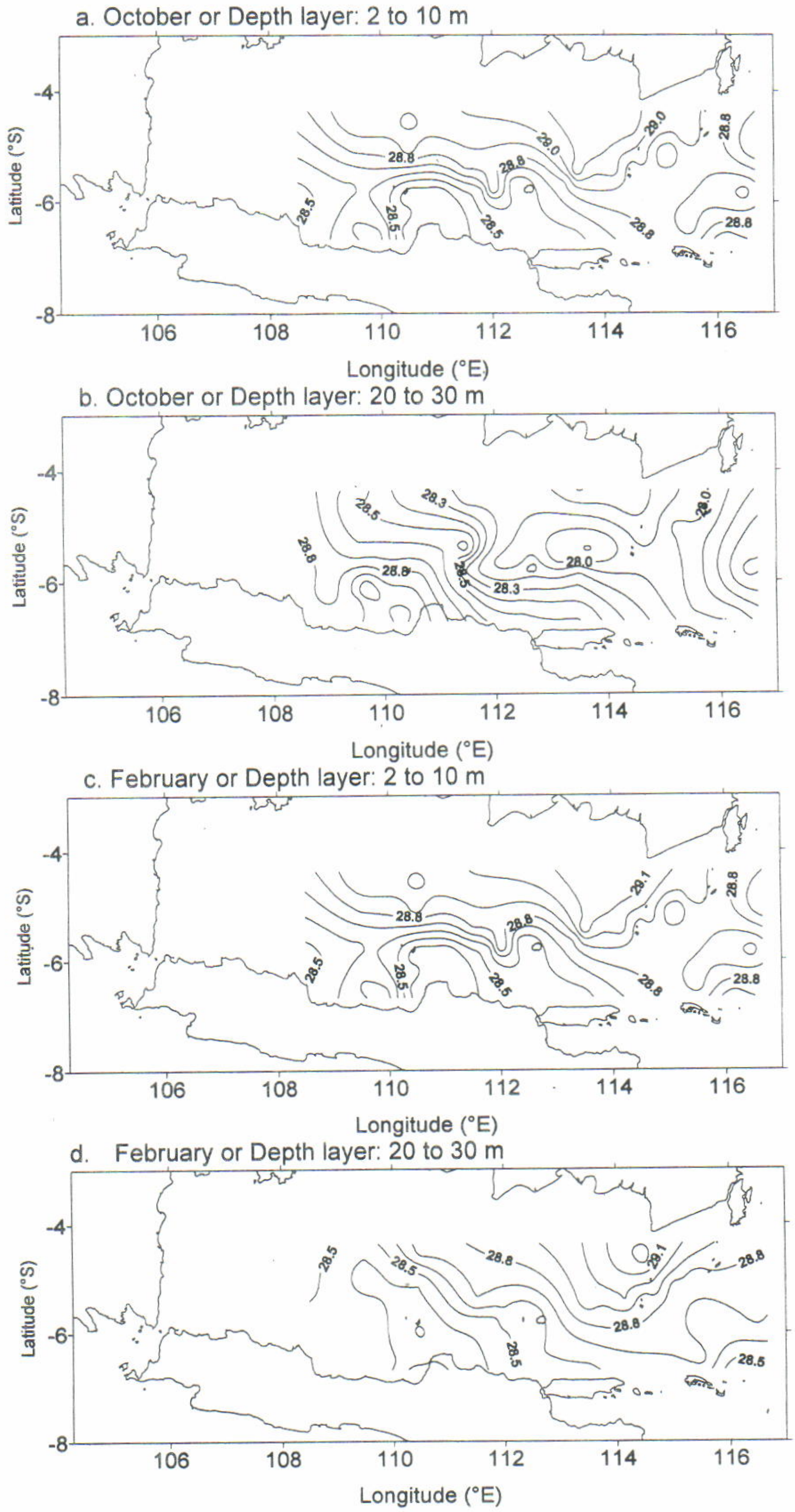


Figure 16. Temperature contour by 2 depth layers observed during acoustic cruises.

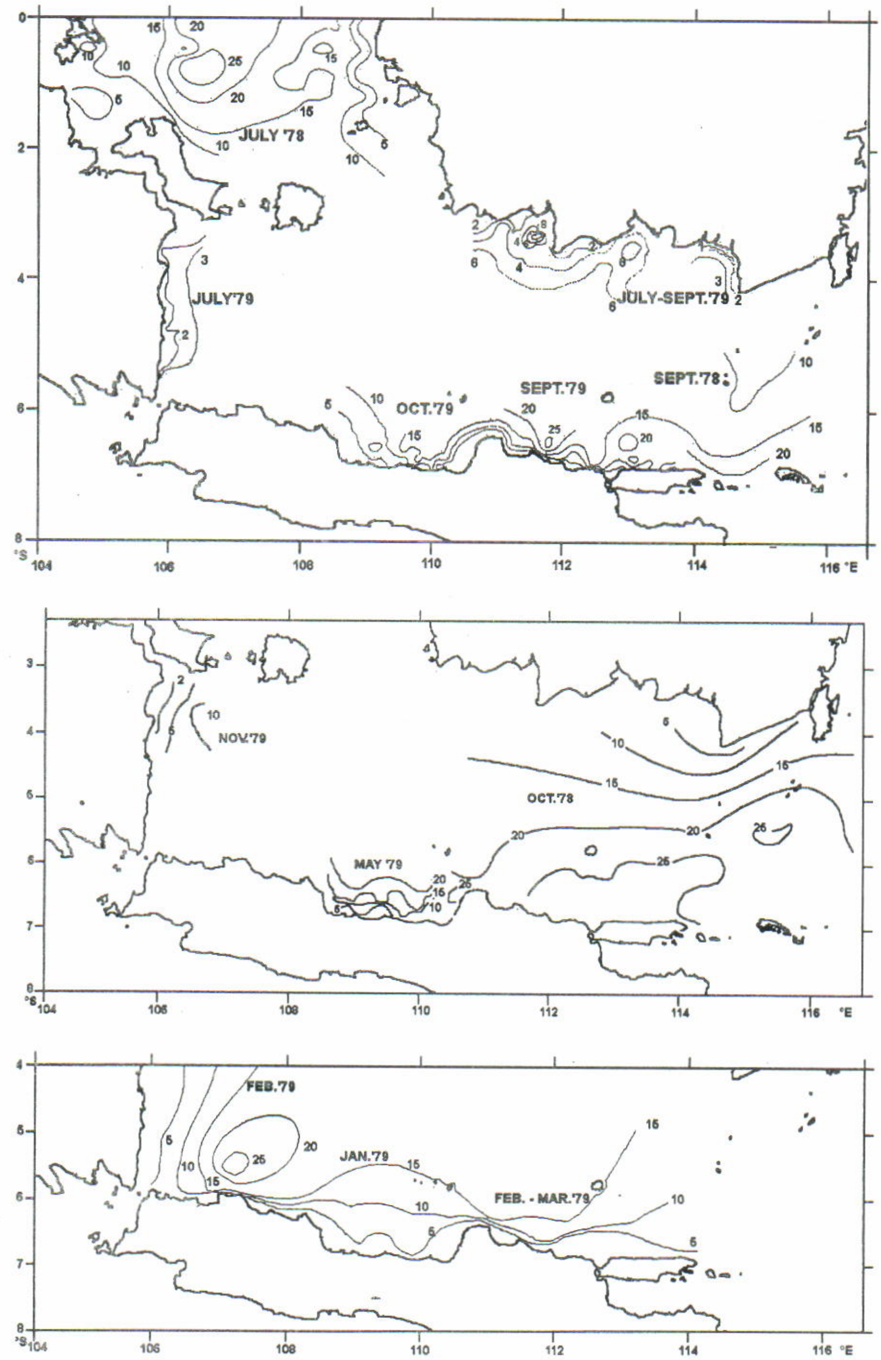


Figure 17. Transparancy distribution of various periods as indicated by sechi disk reading contour.
Source: Beck & Sudrajat, 1979; Dwiponggo & Badruddin, 1980

Oxygen Content

Detail observations were performed in the Pechindon trip covering the sub area from South Makassar strait to the north coast of Java as far as to the depth of 20 m. The results showed that dissolved oxygen content was 4 ml l^{-1} in the near bottom and 5 ml l^{-1} in the surface layer. A similar result was also reported by Doty *et al.* (1963) from the survey conducted in January 1956 which found the value of 4.5 to 4.7 ml l^{-1} in the near bottom layer and by Ilahude (1979) who gave the range of dissolved oxygen at the surface layer to be 4.1 to 4.5 ml l^{-1} in the area of southern part of South China Sea waters. All these figures would reveal a conclusion that whole water mass in the Java Sea seems to be well aerated.

Nutrient

Following the previous investigations, at least three sort of nutrient, phosphate (PO_4), nitrate

a. December to May

b. June-November

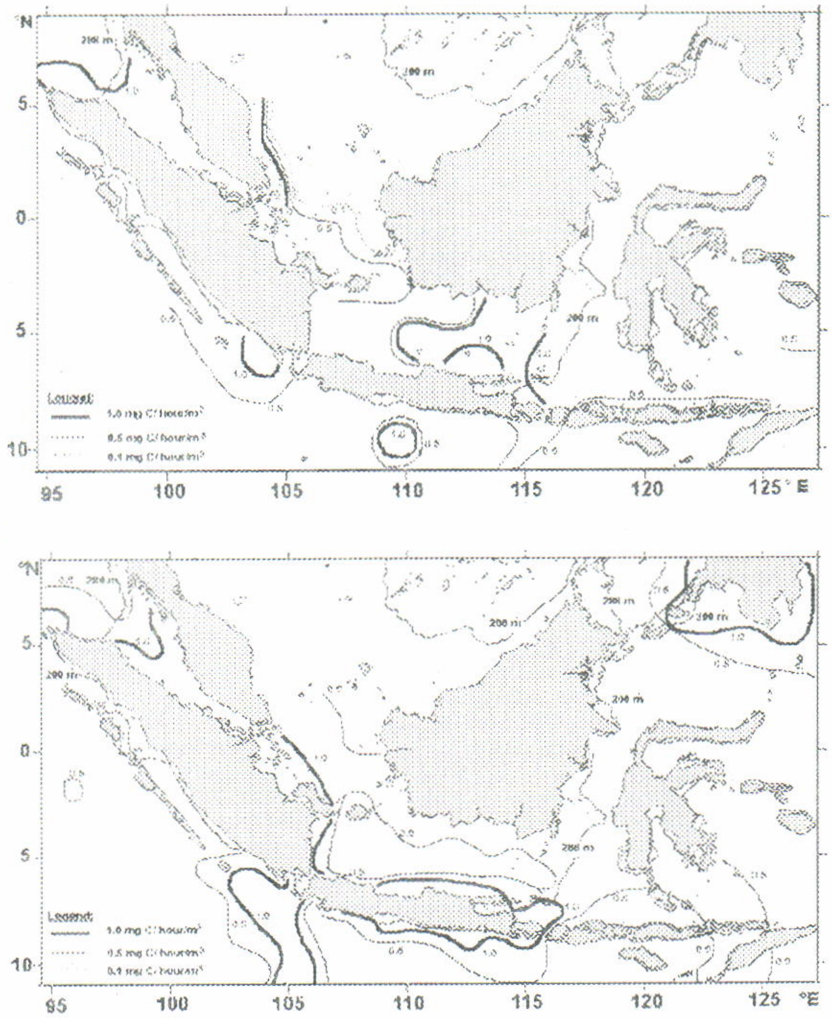


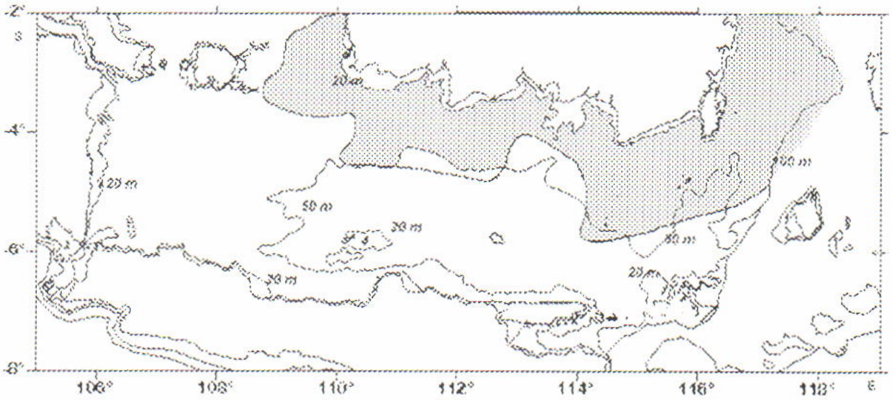
Figure 19. Primary productivity in the Java Sea and adjacent waters during two periods (Soegiarto and Birowo, 1975)

(NO_3), and nitrite (NO_2) had been observed. Delsman (1939) noted that phosphate content observed in April and October was not significantly different, but this value increased slightly as the station to be closer to the coast of Java and Kalimantan. In the area of Southern China Sea, around the equator, Ilahude (1979) noted that the surface concentration of phosphate varied between 0.1 to 0.3 µg A/l, and it was relatively higher during the southeast monsoon than observed values in December, during the northwest monsoon.

Chlorophyl and Plankton

This part is based on the same source of reports as previous sub chapters. Doty *et al.* (1963) gave an argumentation of the land mass effects on the distribution of primary productivity that revealed the same impact on the distribution of chlorophyll in the Java Sea as cited by Nontji (1977). The values of chlorophyll observed from the 2 cruises made during the periods of September to October 1964 and March to April 1965 were almost the same, *i.e.* 0.18 mg m^{-3} and 0.19 mg m^{-3} respectively. The zonation of distribution of the chlorophyll-a in the central part of the Java Sea tended to concentrate in the near coast of south Kalimantan (Figure 20). This phenomenon may be in accordance with another observation using Seawif image (Figure 21), even though the high concentration of chlorophyl frequently consisted of solid debris and tiny particle of sediment generated by a mixing of fresh water and turbulence. Stratification in the neritic area probably generated the different level of planktonic diversity (Table 3). In the near coast of central Java, low diversity of zooplankton may be caused by infertility of the water, as well as of lower fishery productifity of this area.

a. September to October 1964



b. March to April 1965

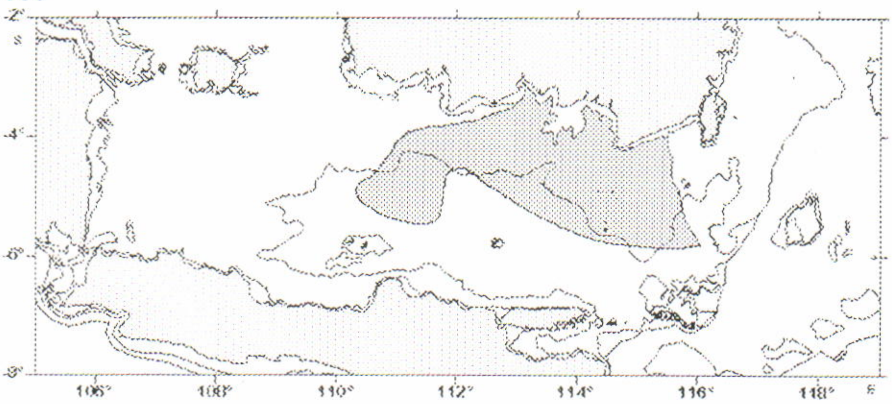


Figure 20. Chlorophyl-a distribution showing the density of higher than 0.2 mg m^{-3} during September to October 1964 and March to April 1965 (Nontji, 1977)

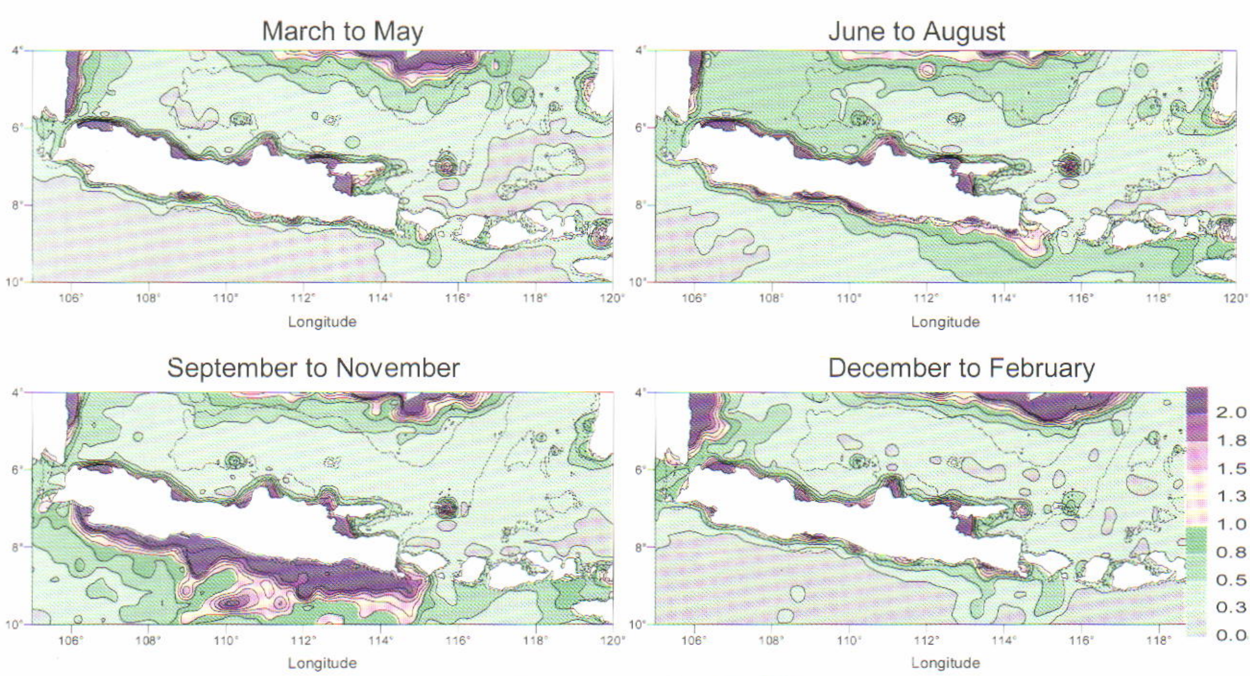


Figure 21. Distribution of chlorophyl a as shown by SEAWIFF image observed in the year 2002.

Tabel 3. Zooplankton Composistion sampled in the Java Sea

Locality	East of Lampung	Bangka-Belitung	Belitung-Java	Madura-Mandalika	North Coast of Central Java
Taxa/periods	**Sep-05**	**Sep-05**	**Sep-05**	**Oct-05**	**Dec-05**
Trochophora sp.	0.0	48.3	0.0	0.0	0.2
Travisiopsis sp.	0.0	0.0	0.0	0.0	0.3
Acartia sp.	1016.7	1060.1	438.1	353.3	34.9
Balanus sp.	0.0	8.3	0.0	0.0	0.0
Calanopia sp.	11.0	0.0	0.0	0.0	0.0
Calanus sp.	892.0	729.6	195.0	171.8	9.2
Corycaeus sp.	204.8	102.3	14.7	93.9	4.9
Evadne sp.	92.7	45.8	73.9	40.9	4.1
Lucifer sp.	6.4	12.8	0.0	2.7	0.8
Microsetella sp.	14.5	31.4	14.7	41.2	0.0
Mysis sp.	28.0	35.7	0.0	0.0	0.4
Nauplius sp.	47.9	125.7	22.1	26.1	1.3
Oithona sp.	145.8	183.6	72.0	124.1	5.0
Oncaea sp.	271.6	321.3	166.4	70.8	3.2
Paracyclopina sp.	0.0	6.7	0.0	0.0	0.0
Penilia sp.	0.0	8.3	0.0	2.3	0.0
Pontella sp.	56.7	18.3	11.0	7.2	0.8
Zoea	77.0	65.1	30.7	4.5	4.9
Bipinaria sp.	8.6	0.0	0.0	0.0	0.0
Sagitta sp.	414.4	186.8	92.1	132.3	19.9
Solmundella sp.	0.0	0.0	0.0	0.0	0.7
Diphyes sp.	0.0	0.0	0.0	2.7	0.0
Anadara sp.	0.0	15.3	11.0	2.3	3.3
Atlanta sp.	89.5	4.9	0.0	5.5	0.7
Limacina sp.	632.8	65.9	0.0	19.8	3.8
Oikopleura sp.	31.0	0.0	0.0	5.4	13.4
Larva of *Cyphonautes*	5.4	0.0	0.0	0.0	0.0
Venerupsis sp.	10.7	0.0	273.1	0.0	0.0
Bipinnaria sp.	0.0	0.0	0.0	2.7	0.0
Total	**4057.4**	**3076.2**	**1415.0**	**1109.4**	**111.8**

In the southern South China Sea, the horizontal distribution of Chlorophyl-a in showed a strong seasonal variation. The values in December 1971 and July 1972 and 1973 were in the ranges of 0.1 to 0.3 mg m^{-3} and 0.2 to 0.6 mg m^{-3} respectively. A comparison between the values of phytoplankton and chlorophyll-a in the southern of Makassar Strait and in the southern South China Sea as reported by the same author (Ilahude, 1978;1979) showed that in the two sub areas the density of phytoplankton seemed to be similar figure. But, in the southern South China Sea the input of material from the river discharge is more important and could be regarded as the main factor giving an impact on the higher concentration of productivity.

Benthic community

Study on benthic ecosystem in the Java Sea are very rare, and only carried out in certain limited area. It is difficult to depict directly the link between benthic community and pelagic fishes. Nevertheless, in certain level, benthic organism living in the sea bed can serve as lower chain in trophic level of pelagic fish. The most detailed study ever done was a study on benthic system of the coastal area of the Java Sea conducted by Indonesian Dutch Senellius II Expedition in July 1984 (Kastoro *et al.*, 1989; Wilde *et al.*, 1989). t covered the area from the north coast of west Java to the north coast of Lombok Island in the Folres Sea. A total of 373 macro and micro benthic taxa were identified which can be divided into 2 taxonomic groups, major taxa and miscellaneous or lower taxa. Other observation from Southern China Sea in the same season (Saeger *et al.*, 1976) provides this information (Table 4). Refigurizing the data of Wilde *et al.* (1989) by regouping the stations by sub area and comparing the structure of taxonomic groups reveal a significant difference on the benthic community structure between subarea (Figure 22).

Table 4. Benthos composition taken from various sub areas

Taxonomic groups	**North Coast of Java[1)]**	**North Coast of Madura[1)]**	**Madura Strait[1)]**	**Continental Slope[1)]**	**Southern SCS[2)]**
Polychaeta	94	71	122	259	3,700
Crustacea	120	248	85	162	500
Mollusca	34	35	39	79	nd
Echinodermata	52	27	13	1	nd
Sipunculoidea	27	13	18	22	nd
Miscellaneous	35	15	24	41	nd
Coelenterata	211	4	9	4	nd
Pisces	45	2	3	12	nd

Remarks: [1)] based on ash dry weight (mg) (Hoekstra, 1989); [2)] based on wet weight (Saeger *et al.*, 1976; Pauly & Martosubroto, 1996)

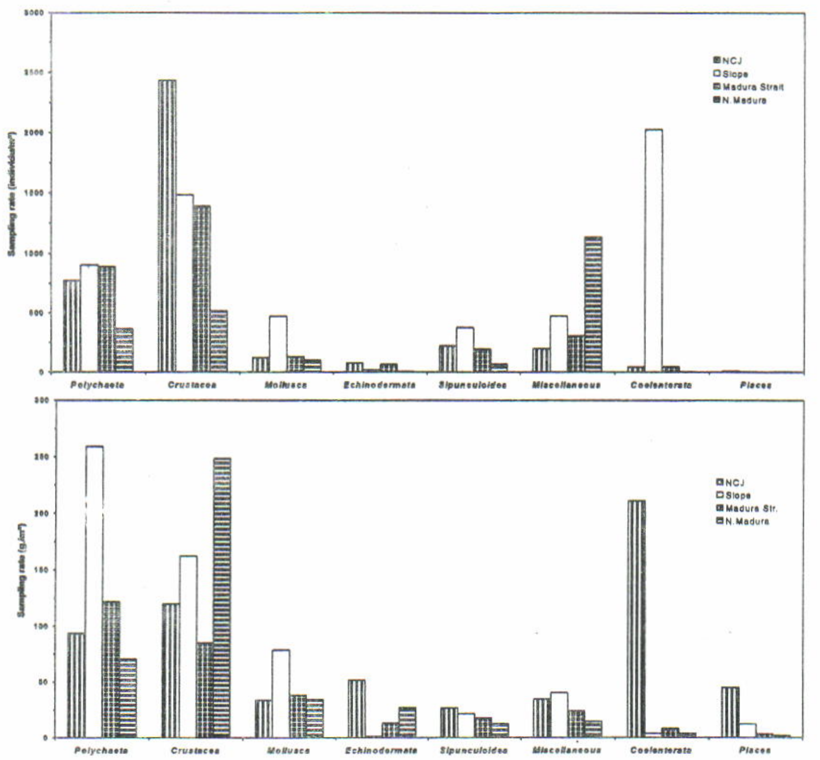


Figure 22. Density of benthic by taxonomic groups and sub areas.
Source: Wilde *et al.*, 1989

In term of evenness, certain taxonomic group tended to dominate the community, but since the size average to be highly vary among the sub area, this figure was not in accord with the biomassa criteria. However, the dominance of the taxonomic group can be defined using criteria of biomass (in weight), in term of frequency of occurrence and in number of taxa as summarised as follow.

As shown above, the crustacea and coelenterata would be important taxonomic group characterising the benthic community in the north coast of Java and Madura. But seasonal fluctuation of these figures would be more interesting, particularly in relation with seaonal variability in the coastal area. In term of diversity, the dominace of species tended to reveal that structure of benthic community of those sub area may be similar. Unfortunately, no confirmation could be made since this information derived from short period observation only.

Table 5. Density of macrobenthos (ind.m^{-3}) of three sub areas observed on September to December 2005

East of Lampung			Bangka-Belitung			North of Central Java		
	Taxonomic group	Density		Taxonomic group	Density		Taxonomic group	Density
b	*Samarangia* sp.	31394	g	*Sinum* sp.	38907	g	*Sinum* sp.	12840
g	*Sinum* sp.	20764	b	*Samarangia* sp.	20855	b	*Donax* sp.	1644
g	*Turritella* sp.	15915	b	*Codakia* sp.	7780	b	*Samarangia* sp.	475
b	*Codakia* sp.	8554	b	*Donax* sp.	6121	s	*Dentalium* sp.	321
b	*Donax* sp.	4857	g	*Turritella* sp.	3839	b	*Tellina* sp.	263
b	*Nuculana* sp.	2756	b	*Tellina* sp.	2305	g	*Turitella* sp.	246
b	*Tellina* sp.	2310	b	*Barbatia* sp.	1714	b	*Vepricardium* sp.	97
b	*Dosinia* sp.	1783	b	*Chlamys* sp.	1318	b	*Codakia* sp.	96
g	*Architectonica* sp.	1646	s	*Dentalium* sp.	1121	b	*Nuculana* sp.	53
g	*Phenacovolva* sp.	1467	g	*Phenacovolva* sp.	936	g	*Phenacovolava* sp.	40
	Average no. taxa	20			17			13
	No. taxa recorded	76			66			46
	Total Bivalve	56361			43438			2741
	Total Gastropoda	42239			46516			13313
	Total Scaphopoda	875			1121			321
	Total Malacostrata							6
	Total Polychaeta							24

Remarks: b = bivalve; g = gastropoda; s = scaphopoda

CONCLUSION

A wide range of components influences the function system of the Java Sea environment. Several aspects involved in the system are geo morphology, climate, hydrology, biology, and human activities.

1. Physical feature of the Java Sea opens a high possibility of a relation to the eastern Indonesian waters and the northern region. The islands surrounding the Java Sea give special impacts on the materials input and circulation in the coastal area. The fluvial sediment yield is the important source determining the substrate type of of sea bed and fertilizing the coastal waters. The rate of deposition of suspended materials from the Java island is considerably high, as being determined by the characteristics of morphology, orography, climate, and landuse of this land.

2. The Java Sea is an extent of the monsoonal climate where the pattern of reversal wind and current has been well know. There are 2 possible sources of variability's affecting the characteristics of the Java Sea.

   - The first is the regular or seasonal variability's. In this case, climate is the main factor governing the hydrological properties of the Java Sea, through a circulation scheme controlled by currents regime. Two major seasons exist in the area over the Java Sea, namely the Northwest and Southeast monsoon. During the Northwest monsoon or rainy season, it undergoes a dilution by freshwater runoff and river discharge, as well as a water mixing process with coastal water mass coming from the South China Sea. Reverse process occurs during the Southeast monsoon or dry season, where high saline oceanic water enters this area from the eastern and northern regions through Flores Sea and Makassar Strait. In general, the westerlygoing current which brings the oceanic water is more regular and significant in influencing the characteristics of the Java Sea water. In this case the proportion of the oceanic water in side the Java sea would be greater than those from southern of the South China Sea and Malacca Strait.

   - The second is the inter annual variability's that is a special case due to the change of global pattern of climatic system, so called as ENSO. It exerts in 2 fashions in term of climatic, it prolongs the period of dry season and then followed by decreasing dilution process. In term of hydrographic, it indirectly influences the water exchange in the Java Sea through the change of global circulation in the Pacific Ocean. In the Java Sea its influence can be noticed that the oceanic water mass from eastern Indonesian archipelago penetrates farther and occupies in the side the Java Sea longer than during normal years.

3. Circulation scheme in this area generates a specific stratification of water mass which is well defined by using salinity pattern distribution. The oceanic water invades to the Java Sea in the periods of June to October, while the coastal water from the northern region replaces it gradually from November to May. The lowest and highest salinity in the middle area were observed during February to March and September or 2 months after the peak of the seasons.

   Horizontally, this salinity based stratification would be very important for the repartition of the pelagic fish concentration. The shifting of high saline water mass can be sought as a factor affecting migratory scheme of the oceanic pelagic fishes. While a tendency of the occurrence of higher salinity in the near bottom layer in the eastern part would be allowable to explain distribution pattern in the Northwest monsoon.

4. Generally, high seasonal variation of primary productivity takes place in the coastal areas, while in the offshore area, there is no significant difference between the 2 major seasons. High productivity in the near coast area is influenced by the input of organic and inorganic materials from the main land.

   Sedentary and demersal communities. The influence of seasonal change of water condition on the spatial distribution of most of demersal species in the coastal areas is apparent. Different assemblage of demersal fishes by areas reveal that each area is occupied by different community being charaterized by certain predominance species. Similar trend of discrimination of benthic community seem to be obvious along coastal area of north of Java.

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