GENERAL FEATURES OF JAVA SEA ECOLOGY

B. SADHOTOMO, J.R. DURAND

ABSTRACT

Monsoon climate is the main factor governing the characteristics of the Java Sea waters. Seasonal water exchange with the Flores Sea determines the distribution pattern of abundance and occurrence of the pelagic fishes. Groups of oceanic and neritic species enter the Java Sea, following higher salinity waters coming from the eastern archipelago, in young stage. While group of coastal one tends to stay in the Java Sea along the year.

Interannual variability, as indicated by oscillation of the rainfall, could be an important external factor controlling long term variability of the abundance of pelagic fishes in the Java Sea.

KEYWORDS : Java Sea, environment, ecology, distribution.

ABSTRAK

Iklim muson merupakan faktor yang menentukan sifat-sifat perairan Laut Jawa. Pertukaran massa air secara musiman dengan Laut Flores menentukan pola penyebaran kelimpahan dan keberadaan ikan pelagis. Kelompok ikan oseanik dan neritik muda memasuki Laut Jawa mengikuti massa air bersalinitas lebih tinggi yang datang dari Timur. Sementara kelompok ikan pantai cenderung timggal di Laut Jawa sepanjang tahun.

Variabilitas iklim tahunan sebagaimana ditunjukkan oleh perubahan rataan curah hujan merupakan faktor eksternal yang berperan mengatur perubahan jangka panjang kelimpahan ikan pelagis kecil.

KATA KUNCI : Laut Jawa, lingkungan, ekologi, distribusi.

The Java Sea is located between the main islands of the archipelago, which are occupied by more than 150 millions inhabitants. In 1991, Java Sea fisheries production represented more than 30% of the national marine production. In relation to the importance of the marine resources and to the fast development of the exploitation, the knowledge on its environment should be a priority, but the lack of recent and comprehensive data is obvious.

Studies on environment had been pioneered and conducted partially by the Dutch government in the beginning of this century, covering exploitation, climatological, biological and hydrological aspects. Unfortunately, those activities had terminated since the war and no comprehensive studies on this topic have been performed since. However, general synthesis and reviews, related to these topics, had been presented previously (Durand and Petit, 1995; Potier *et al.,* 1989; Potier and Boely, 1990; Boely *et al.*, 1991).

In this paper, we present a brief review and exploration on previous existing information. We also use observations made during acoustics cruises (Petit *et al.,* 1995a), as well as bio-ecological results of the studies conducted by the Pelfish Project. Two essential variabilities of the Java Sea ecosystem have to be taken into account with emphasis on bio-ecological features :

- the influence of monsoon in relation with internal process in the Java Sea;
- the long term change of climatic parameters and interannual oscillation of precipitations.

PHYSICAL FEATURES

The great Sunda Shelf extends from the Gulf of Thailand southwards through the South China Sea and Java Sea represents its south-eastern zone (Fig. 1). It is a large and shallow water mass which has been risen up several times during Pleistocene (Emery *et al.,* 1972). During these periods, Sumatra, Java and Kalimantan were joined together with Malacca Peninsula.

The Java Sea is well delimited on 3 sides : it is bordered by 3 big islands, Sumatera in the West, Java in the South and Kalimantan in the North. On the contrary, the eastern part is relatively wide opened to the Flores Sea. In the North-west, it is connected to the Southern China Sea by Karimata and Gaspar Straits, while in the South-west, the Sunda Strait connects the Java Sea with the Indian Ocean. This situation means that the marine waters quality -- and hence the bio-ecological features -- is under the influence of two main phenomena :

- The discharge of continental fresh waters and its variability, both seasonal and interannual. It is considerable -- mainly through Kalimantan rivers -- and will explain partly some low seasonal salinities.
- The exchanges with adjacent marine bodies through the main straits quoted above and the eastern opening towards Flores Sea; the latter seeming to be the more important.

Java Sea total area stands more or less to 450,000 km^2. Its mean depth is about 40 m and in the longitudinal (East-West) axis, its bathymetric profile tends to slope with the deepest part lied in the East and ended in the continental slope. Many coral reefs and islands lie in the Java Sea and extent from the West to the North-East, which traditionally correspond to fishing grounds of pelagic fishery (Fig. 1).

The most part of bottom substratum of the Java Sea is constituted by silt and formed by highly dense mud layer, with large muddy bed in the North-East and central area which are mixed with coral and shell debris (Boely *et al.*, 1991; Emery *et al.*, 1972). Sandy mud is frequently observed in the South part of Kalimantan, North of Madura and near the coast, rocky outcrops associated with coral formations are observed.

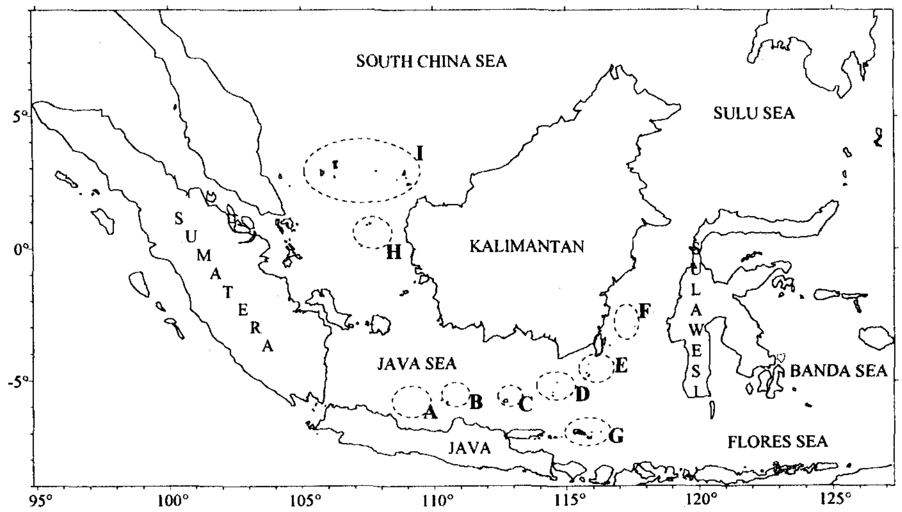


Figure 1 **Location of the fishing zones of seiners in the Java Sea.**
Gambar 1 **Lokasi daerah penangkapan purse seine di Laut Jawa.**

A = West of Karimunjawa Is.	**F = Lumu-lumu Is.**
B = Karimunjawa Is.	**G = Kangean Is.**
C = Bawean I.	**H = Tambelan I.**
D = Masalembo Is.	**I = Anambas - Natuna Archipelago**
E = Matasiri Is.	

CLIMATIC FACTORS

The monsoon factors

The Java Sea and adjacent waters are governed by a monsoon climate which affects seasonally their hydrographical condition. The monsoon could be defined as a semi-annual reversal of wind and current regime. Following definition given by During (1970) and Fieux (1987), the monsoon regime of wind and current over area could be defined by considering the direction of the prevailing winds and currents changes by more than 90°. The areas, influenced by this monsoon, could be expressed in terms of atmospheric and ocean parameters (Pedelaborde, 1965).

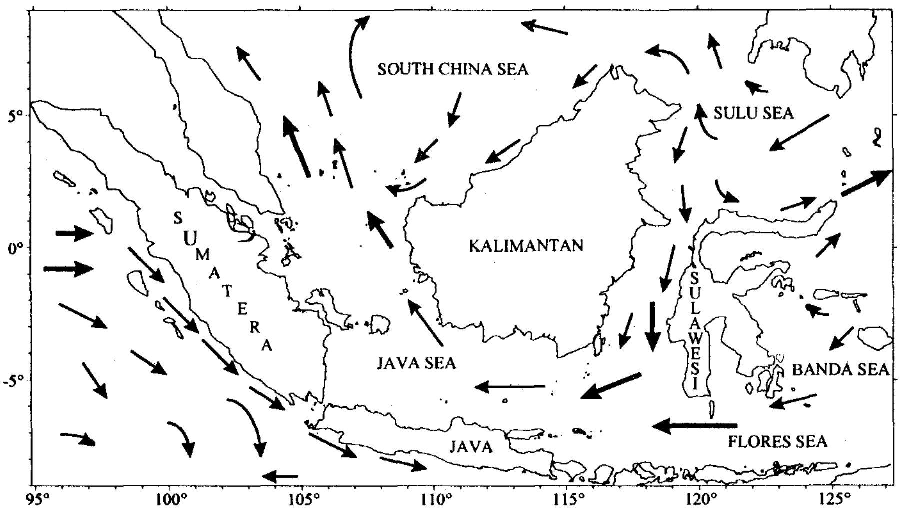
The monsoon clearly impacts a semestral change of hydrographic and atmospheric parameters that seasonally determine the sea water properties of the Java Sea. The surface currents tend to follow the direction of the prevailing winds which gradually change along the year. These wind-driven currents just imply, at first, the movement of surface or near surface waters, then, vertical mixing becomes obvious, and finally, these currents engender a shifting of water mass from the eastern part during the South-East monsoon (July-October) and from the North and West during north-west monsoon (November-February) with lower intensity. The reversal occurs during July-October and December-February. These phenomena have been described exhaustedly (Veen, 1953; Wyrtki, 1956a; 1961) and some reviews on these results have been cited and reviewed in several articles (Potier *et al.*, 1989; Durand and Petit, 1995). In general, this pattern could be summarized as in Figure 2.

As a consequence of the semi-annual change of climate, this seasonal movement of the water masses raise the important issue about their relations to the eastern part of Indonesian archipelago and the South China Sea, respectively, through water exchange with the Flores Sea during S-E monsoon and with Karimata Strait during N-W monsoon, respectively.

During the S-E monsoon, the currents come from the East, bringing higher salinity and lower temperature waters from Flores Sea. At the beginning of this season, the sea front clearly shows the direction of this wind-driven current (Emery *et al.*, 1972; Wyrtki, 1956b; Gastellu-Etchegorry and Boely, 1988), and the higher salinity waters, shifting from the East.

Recent salinity data showed that an intrusion of oceanic water was still observed during October 1993 (Fig. 3). The saline or oceanic waters gradually penetrate the Java Sea and the current does not totally replace the lower salinity water. In the contrary, these phenomena will be reversed during N-W monsoon. Consequently, in the eastern part of the Java Sea and Flores Sea, the salinity always exceeds 32.5‰ while in the western part, coastal areas and Southern China Sea where the effects of discharge of fresh waters from rivers become important, it varies between 30-32‰.

A .South-East monsoon



B. North-West monsoon

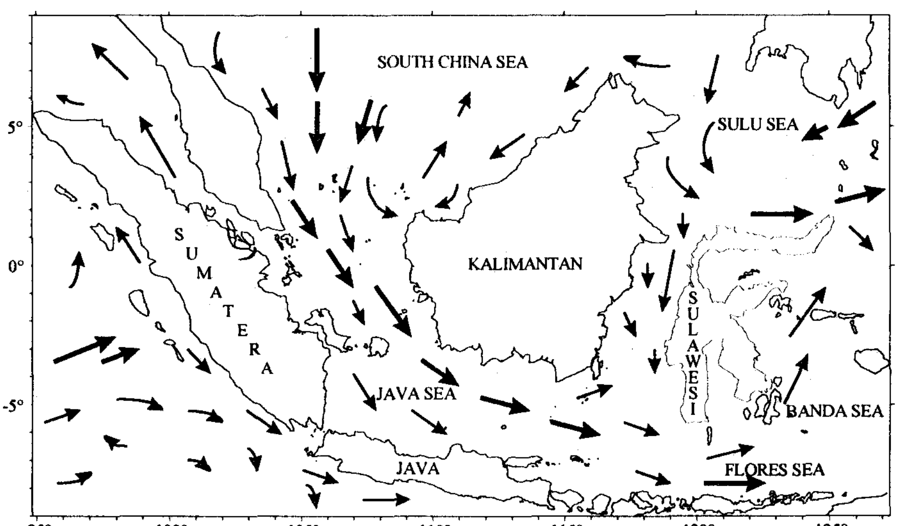


Figure 2 **Average current direction during North-West and South-East monsoons (from Wyrtki, 1957; 1961).**

Gambar 2 **Rata-rata arah arus selama musim barat laut dan musim tenggara (dari Wyrtki, 1957; 1961).**

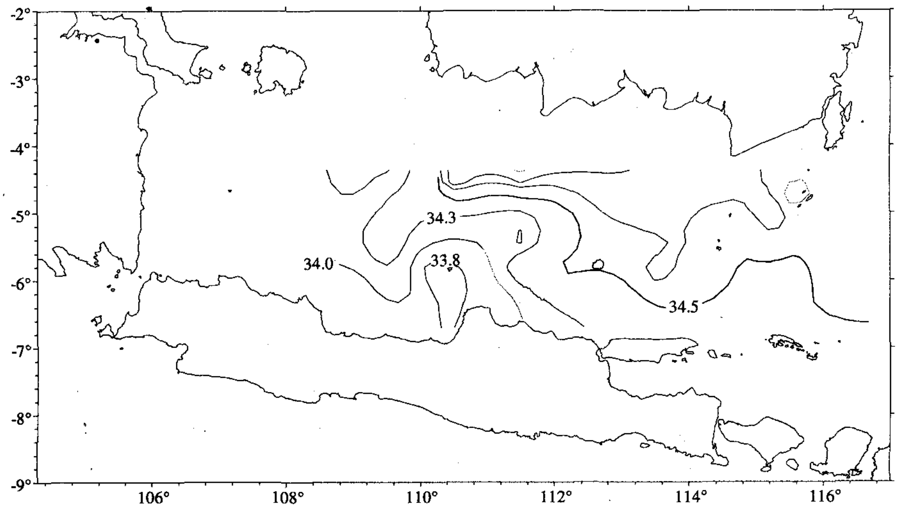


Figure 3 **Mean salinity contours observed in October 1993 (Cruise 34) showing the shifting of saline water from the East.**
Gambar 3 **Rata-rata salinitas yang diamati pada bulan Oktober 1993 (cruise 34) menunjukkan perubahan air asin dari Timur.**

During the N-W monsoon, the rainfall, as recorded in some small islands (Wyrtki, 1956a and Fig. 4), and the discharge of river flow from the mainlands as well, increase gradually and attain their peaks in December (Directorate General of Water Resources, 1988 and Fig. 5). In this period, the salinity of the coastal area will be lower due to dilution by run-off and river discharge. Also, simultaneously, this area undergoes an enrichment process which occurs with the input of organic constituents and nutrients from the lands. This process is likely to be of great importance for most of young and early life stages. Those above descriptions support our conclusion that circulation of the sea waters and land mass effects of the large islands -- and, of course, combination of both -- should be the main factors influencing the variability of the Java Sea ecology.

Interannual variability

A coherent fluctuation of global pattern of oceanic and atmospheric conditions, called an oscillation, has an important impact on climate, as shown in terms of regional rainfalls. This anomaly occurs together with major changes in current and temperature in the eastern equatorial Pacific, the so called El Nino. The two phenomena are jointly referred as El Nino-Southern Oscillation, or ENSO. The influence of ENSO, on South East Asia, has not yet been comprehensively mapped (Nicholls, 1993).

Serial rainfall data, from Kalimantan stations, were analyzed in order to check relation -- if any -- between interannual variability and fishery productivity in the Java Sea (Fig. 6).

Rainfall rate tended to increase since 1990. Based on model of climatic change prediction in South East Asia region, percentage change of precipitation in this area was estimated to be 0-15% and 10-15% during NW and SE monsoon, respectively (Henderson-Sellers, 1993). This tendency is simultaneously followed by the global air warming as well. The drought occurred in 1982-1983 (as indicated clearly in Figure 6) could be classed as an ENSO event. Nevertheless, it is difficult to confirm that the dislocation of the rainfall and these results from simulations, as shown on the next page, were strongly related to the ENSO events.

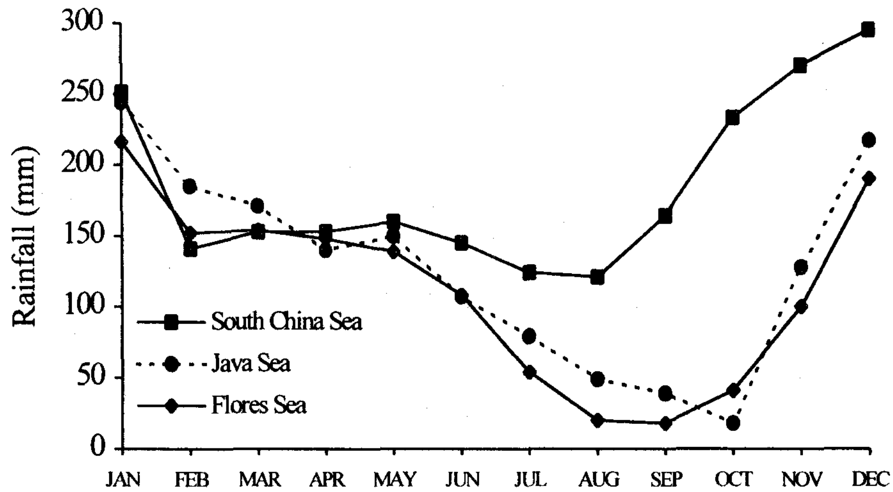


Figure 4 Rainfall at three areas (adapted from Wyrtki, 1956a).
Gambar 4 Curah hujan di tiga daerah (diadaptasi dari Wyrtki, 1956a).

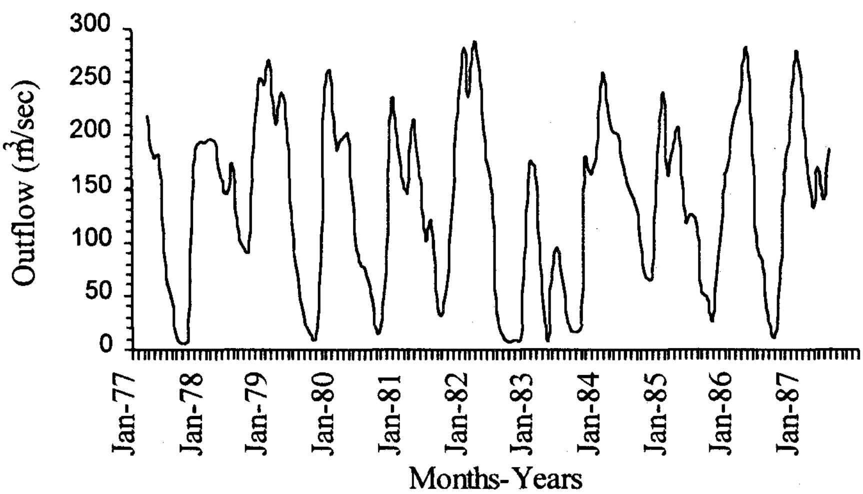


Figure 5 Monthly discharge of Negara River, South Kalimantan.
Gambar 5 Debit air bulanan dari Sungai Negara, Kalimantan Selatan.

The impact of the ENSO event in the years 1982-1983, 1987-1988 and 1991 which involved dislocation of rain fall distribution, was not indicated directly by clear changes in Java Sea fish abundance. In fact, the strong yield increase in 1985 and then in 1991-1992 (Potier and Sadhotomo, 1995) could not be sought as the influence of ENSO events alone. We can notice that the yield of seiners fishery depended on the contribution of typical oceanic species which enter Java Sea from the eastern areas. The increase of salinity and/or duration of saline waters in the Java Sea as an influence of ENSO on hydrographic properties of the Java Sea would be examined, using at least, the salinity distribution pattern. Combination of the local factors such as desalination and water exchange could be important as they could affect the accessibility of pelagic fish in the Java Sea.

Unfortunately, no hydrographic observations were done during those periods. Furthermore, the fishery as well as fishing pattern has changed as a result of economic trends and investments of the fishing boat owners (Potier and Sadhotomo, 1995).

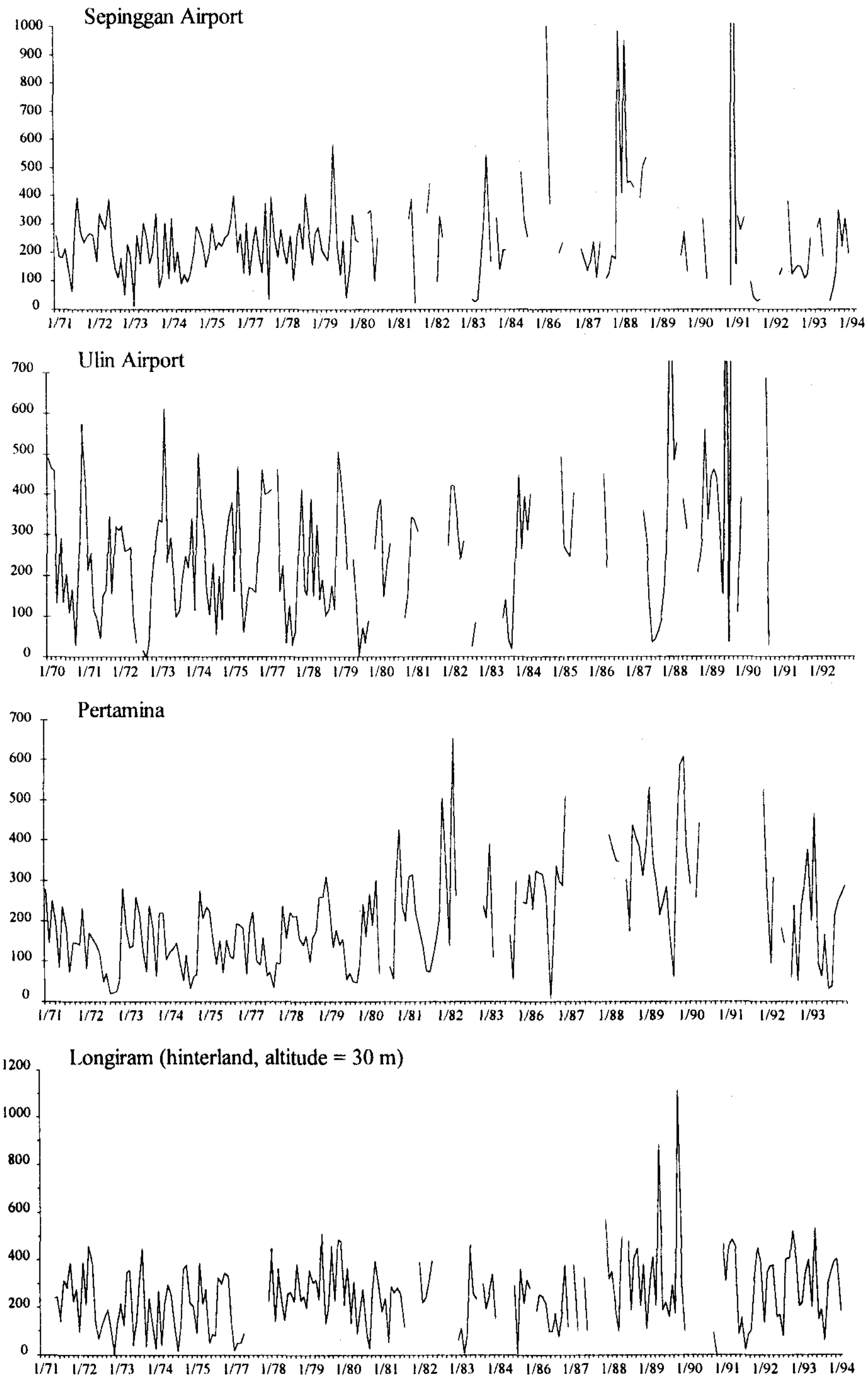


Figure 6 **Historical data of the rainfall recorded at four Kalimantan meteorological stations (Source: Agency for Meteorology and Geophysics BMG, Jakarta).**

Gambar 6 **Data historis curah hujan yang tercatat di empat stasiun meteorologi Kalimantan (sumber : Badan Meteorologi dan Geofisika, Jakarta)**

Distribution of species and populations

Based on the catch of seiners, Potier and Sadhotomo (1995) showed that three groups of species exist in the Java Sea, namely oceanic, neritic and coastal species. The oceanic group is composed of *Decapterus macrosoma, Amblygaster sirm* and *Rastrelliger kanagurta*; while the neritic and coastal ones consist mainly of *Decapterus russelli, Selar crumenophthalmus* and *Sardinella gibbosa*. We tried also to examine species composition data derived from daily sampling done simultaneously with length frequency measurements, which gave similar results. The oceanic group of species consists of *D. macrosoma, A. sirm* and *S. lemuru* (in the commercial category, it is combined with *A. sirm*), while *R. kanagurta* tended to be « closer » to *D. russelli*. than to the first group. The rest was composed by *S. crumenophthalmus, S. gibbosa, Dussumeiria acuta, Selaroides leptolepis* and *Megalaspis cordyla* (Fig. 7).

First evaluation on this topic was given qualitatively by Dutch scientists before the war. Based on this information, Hardenberg (1938) submitted an hypothesis of the distribution of *Decapterus* populations in the Java Sea. He gave three possible populations of the genus of *Decapterus, i.e.*, East population from the Flores Sea, and West populations coming from the Indian Ocean through the Sunda Strait and the South China Sea. The second one, was given by Sadhotomo and Potier (1995), which broke down the distribution of fish more precisely into species and zonation. In fact, those studies were orientated towards a tentative migration scheme, and without genetics studies and/or marking results, it remains difficult to totally demonstrate its validity.

Reproduction and fish size distribution

Studies on early life history had been conducted during colonial era but no intensive study continued until Atmaja *et al.* (1995) presented their maturity observation of some pelagic species in the Java Sea. Delsman (1926) found the floating eggs of some pelagic species. He identified them as the eggs of *Caranx kurra, C. macrosoma, C. crumenophthalmus* and *Scomber kanagurta* (as currently used as synonymous of *Decapterus russelli, D. macrosoma, Selar crumenophthalmus, Rastrelliger kanagurta*) and some other coastal species.

Reanalyses of recent maturity data gave clearer confirmation to study (Atmaja *et al.*, 1995). There were only few mature fish found in the samples, even from the area of eastern part of the Java Sea (Fig. 7). It means that the oceanic and neritic group of species do not lay their eggs in the Java Sea. Was the results of Delsman a special case? He did not give observation on maturity, so it is impossible to confirm his finding of mature fishes in the Java Sea and its relation to the occurrence of eggs of pelagic species in the same time, as described in his report. Also, there is no other study on eggs and larvae identification that can be used for confirming the previous result. Another possibility was the occurrence of sea water anomalies in the Java Sea at the time of the sampling, June 1920. According to the association of El Nino with East monsoon drought in Java during 1919 (Quinn *et al.*, 1978), the period of that sampling could still be under this influence, about 1-2 years after the peak of El Nino event in 1918. During the eggs sampling, the salinity was 32.6‰, but there was no explanation whether he observed those pelagic eggs accidentally, or whether they were regularly found every year.

If we look at the spatial distribution of sizes and its monthly progression for oceanic and neritic species, it shows a possibility of immigration from oceanic waters, outside Java Sea sampling areas (Sadhotomo and Potier, 1995). This hypothesis seems to be strongly accepted. In this case, *D. acuta* is the most possible as local population. It can be seen (Fig. 8), that this species tend to stay in Zone A (north coast of Central Java), while statistics of the landing showed that *S. gibbosa, M. cordyla* and *S. crumenophthalmus* are sometimes caught by seiners in the area of "more" oceanic waters, such as Masalembo and Makassar Strait (Potier and Sadhotomo, 1996).

In general, the size distributions tend to follow West-East direction : smaller fishes in the western part and larger ones in the eastern part of the Java Sea. Petit *et al.* (1995b) confirmed this general trend on the basis of Target Strength values.

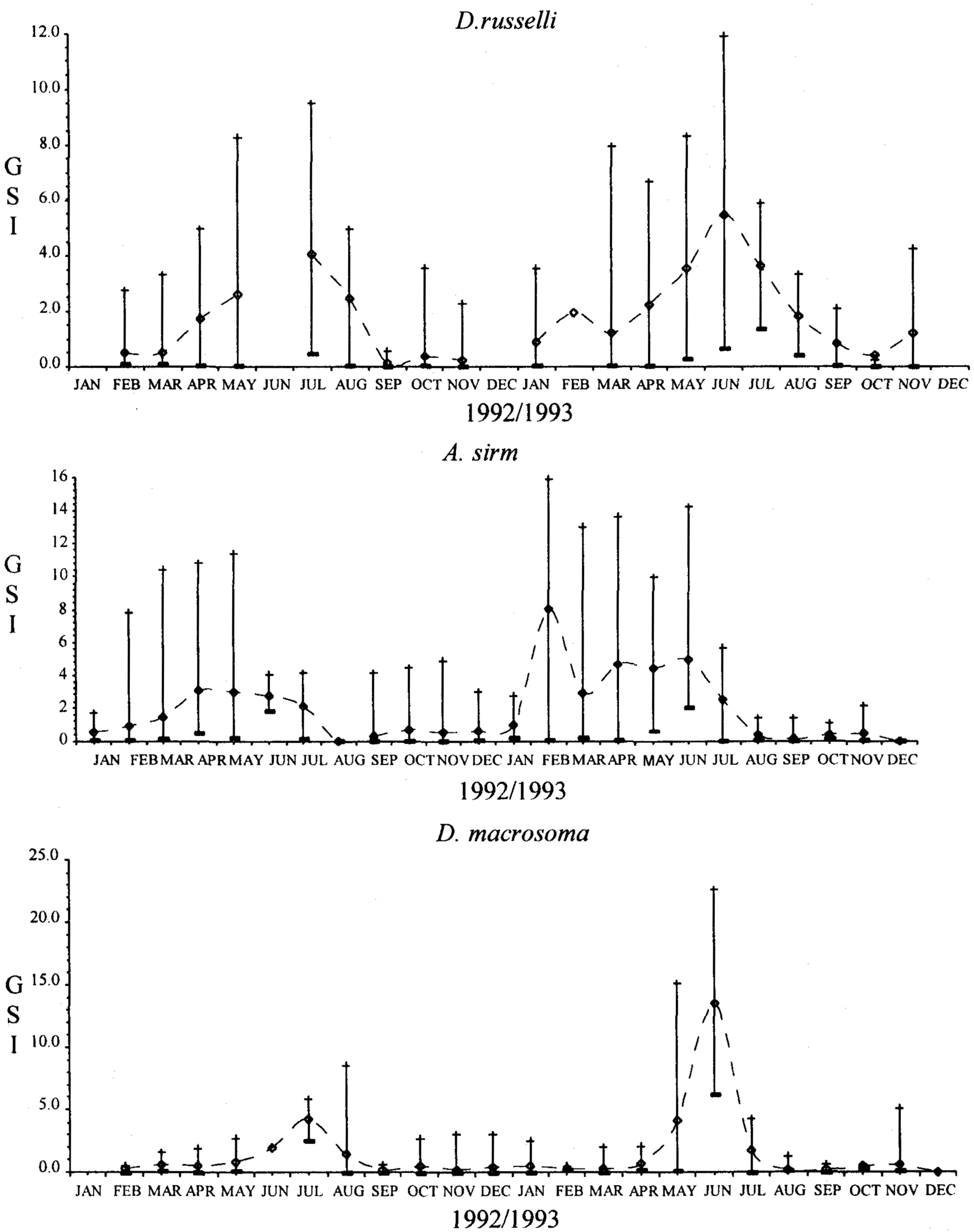


Figure 7 **Monthly evolution of Gonado-Somatic Index (GSI) and deviations for three main species in the years 1992-1993.**

Gambar 7 **Perkembangan bulanan Gonado-Somatic Index (GSI) dan penyimpangan tiga jenis ikan utama pada tahun 1992-1993.**

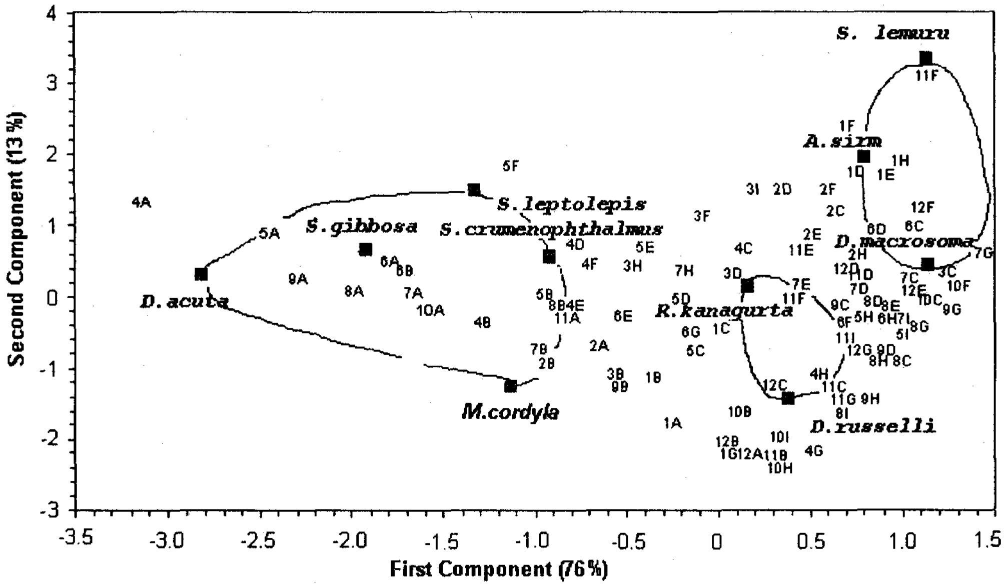


Figure 8 **Superimpose plot of species and monthly fishing zones using the weighted Principal Conponent Analysis (P.C.A.)(1 to 12, denote the months of sampling; A, B, C... are codes of the fishing zones as presented in the Figure 1.**

Gambar 8 **Plot superimpos dari spesies dan zona penangkapan bulanan dengan mempergunakan P.C.A. yang diboboti (1 sampai 12, menunjukkan bulan-bulan percobaan; A, B, C... adalah kode dari zona penangkapan seperti tercantum pada Gambar 1.**

Length-based evaluation indicated that small fishes enter the fisheries during the inter-monsoon (May-July) in the areas between Karimunjawa and Bawean Islands (Sadhotomo and Potier, 1995). In June, smaller fishes tend to stay near Karimunjawa Islands. This period can be regarded as the first recruitment of the main pelagic species in the Java Sea.

CONCLUSION

The monsoon climate could be sought as the main factor governing the hydrological properties of the Java Sea, with the salinity as the most important parameter. Exchanges with the oceanic waters (*i.e.*, Flores Sea) are characterized by seasonal changes of salinity which control seasonal abundance and concentration of the fish. As a consequence, the activities of the fisheries will also reflect this cycle. In terms of seasonal process, desalinization of whole or, at least, a part of the Java Sea which immediately follow the higher rainfall, river discharge and run-off, during North-West monsoon, would determine the natural life cycle of the most pelagic species as well as the direction of the migration of neritic and oceanic groups of species.

Interannual variability of the Java Sea environment could be a special case due to the global pattern of climatic system, namely the ENSO. It exerts in two fashions :

- In terms of climate : ENSO event frequently causes longer dry season in the area around Java, that enables desalinization to decrease.
- In terms of hydrography : El Nino, in Western Pacific, indirectly influence water exchange in the Java Sea through the change of sea water level and global circulation in the Pacific. In the Java Sea, it could be hypothesized that the oceanic water mass (*i.e.*, from the eastern Indonesian archipelago) penetrates farther and stays longer than during normal years.

These anomalies could probably be detected through the monthly distribution pattern of average surface temperature in long term periods. Nevertheless, it would be very premature to conclude that there is a direct correlation with, for example, high productivity of the fisheries in 1985 and 1991-1992... Both the lack of long-term data on the environment and the influence of other factors, such as the behaviour of the fishermen or the development of the fleet, prevent from having in-depth analysis of such hypothesis.

The most important conclusion, for exploited pelagic species in Java Sea, is given through the spatial heterogeneity of the species distribution. There are, at least, two types of population groups in the Java Sea. The first one is the group of resident species that spend their whole life in the Java Sea and depend on the functioning of coastal waters. The species of this group are included in the coastal population group. The second one is the visitor species group, which, at the time being, plays the major part in pelagic fishery. These species stay in the Java Sea for a part of their life span, in the young age only, meaning that adult stages and their reproduction mainly take place outside Java Sea, in the eastern seas of Indonesia.

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DISCUSSION

(Chairman Dr. PASARIBU)

Dr. NURSALAM

Q : - Do you have any data about nutrient input from the rivers because it is very important for the habitats of the Java Sea ? Have you any data from Kalimantan, Sumatra or Java which could allow to calculate the sedimentation rate that could affect the quality of the Java Sea waters ?

A : - We have no data about it. My opinion is that the fish enter the Java Sea not because of the nutrient only, but because of eventual other factors. We have no additional information on these factors. We shall try to complete our knowledge on the preferences and the reasons why fish enter the Java Sea.

Dr. NURZALI

Q : - My question is about the three groups of species, the oceanic, the neritic and the coastal ones. What criteria did you use to delimit these three families ? Is it the distance from the shoreline or oceanographic parameters which have been used to discriminate these groups ?

A : - Mr. Potier was the first to sort these groups based on information about the frequency of occurrence of these species and according to their areas and distance from the shoreline, of course. Then, we tried to find out information on salinity in these related areas, using environmental data of salinity profiles extracted from former publications. We have put arbitrary conditions on salinity : 34 ‰ has characterized the oceanic species. If more frequent species were found in waters with a salinity higher than 34 ‰, we decided to classify them as oceanic species and lesser until 32 ‰ have been considered as neritic species.

Q : - Do you think the oceanic group stays only in the center of the Java Sea, near Kalimantan or anywhere else where the salinity is lower ?

A : - *Decapterus macrosoma* has never been found near the coast of Kalimantan, *Ambligaster sirm* either. Sometimes, fishermen catch both near the central part of the Java Sea, where the salinity is about 32 ‰. It has been said before that 34 ‰ was an arbitrary unit used to define this criterion; I must specify that this salinity is the most suitable for these species; of course, these species have tolerance to live in lower salinity, but not less than 32 ‰. Therefore, this value has been considered as the limit for the neritic species. Sometimes, *D. russeli* and *D. kanagurta* are caught in Tanjung Sate, in the Karimata Strait, where the salinity is lower than 34 ‰. We conclude that *D. russeli* and *D. kanagurta* have weighting of salinity tolerance.

Q : - This is about the brackish and coastal waters. From our point of view, there is a relationship between pollution from the river discharge especially from the Java island, along which there are many brackish water parts, and the fact that there are quite few fish living in coastal waters. Dr. Widodo told us there were nearly 23,000 fish species in the Indo-Pacific.

A : - We have no information about that relation, but we can say that the impact of the pollution may be effective on these coastal species; our samples have been taken from seines, not from other gears, and if you have samples from other source, maybe we could have more details.

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