SPATIO TEMPORAL DISTRIBUTION OF SMALL PELAGIC FISH IN THE JAVA SEA

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ABSTRACT

Time spent in seeking fish schools and potential fishing areas is the main source of fuel consumption, and it is a significant factor in raising the cost of fishing operation. Therefore, knowledge of the distribution pattern and aggregations of commercial fish in space and time is of considerable financial value to the fishers and fishing industry because it will assist them to reduce the time and fuel consumption of the boats in locating the rich fishing grounds. To gain understanding of such knowledge, study on the spatio temporal distribution of small pelagic fish has been done in the Java Sea using commercial fishing data and hydro acoustic. It was found that abundance of pelagic fish was seasonally variable in the Java Sea, reaching its peak in May for the inshore area and September for the offshore area. It was mostly driven by fluctuations in the abundance of one dominant species, *Sardinella* spp. in the inshore and *Decapterus* spp. in the offshore. The high abundance occurred in the areas around the vicinity of small islands. Based on the cluster and PCA analysis, *Rastrelliger* spp., *S. crumenophthalmus*, and *Sardinella* spp. were considered falling into one group and found to be abundant between April and July.

KEYWORDS: **spatio temporal distribution, small pelagic fish, Java Sea**

INTRODUCTION

The Java Sea, which is hydrologically influenced by Pacific Ocean and the Indian Ocean, is one of important fishing areas in Indonesia. A substantial part of the growth in the catch has come from this area. Indeed, with only 7% of the total fishing area, the Java Sea contributed to amount of 32% to the total marine fish catch (DGCF, 2007).

Between 1968 and 1980, the main fishing gear used in catch growth from this area was the bottom trawl with main target species of shrimps and demersal fish. By the end of the 1970s, the number of trawlers exceeded the license available by an estimated of 40% in the Java Sea area, and fishing effort was estimated to be approximately 20% above the level required to reach the maximum sustainable yield (Potier & Sadhotomo, 1995a).

Conflicts with small scale inshore traditional fishers, particularly those operating fixed gears, had become a major political issue. Between 1981 and 1983, a ban on the use of the bottom trawl came into effect throughout the west Indonesia. Most of these trawlers, since then, were converted to pelagic fishing, particularly purse seiner, and gill neter.

Pelagic fishery in the Java Sea has become important after 1980. The fishery rapidly develops following the increase of purse seine fleet to a bigger and powerful vessel. Amongst the important species target of pelagic fishing is a community of small coastal pelagic fish, consisting scads, *Decapterus* spp.; sardines, *Sardinella* spp.; Indo-Pacific mackerels, *Rastrelliger* spp.; and trevallies, *Selar* spp. (Widodo, 1995).

The Javanese fishers, so far, rely on their traditional knowledge of habitat to search fish schooling and to target their fishing efforts. They still practice hunting in locating their fishing grounds, although they utilized fish aggregating devices and light as auxiliary devices for attracting fish schooling in their fishing strategies (Potier & Petit, 1995). Time spent in seeking fish schools and potential fishing areas is the main source of fuel consumption, and it is a significant factor in raising the cost of fishing operation.

It is of great importance to understand the distribution pattern and aggregations of commercial fish in space and time. A better understanding of such knowledge is of considerable financial value to the fishing industry because it will assist them to reduce the time and fuel consumption of the boats in locating the rich fishing grounds. From resource management point of view, ensuing greater efficiency of the commercial operations is important, as it would help to make operations more profitable. Reliable information of fish distribution and abundance and its aggregation pattern is required from the scientific community for this purpose.

Traditionally, fish distribution and abundance have been indirectly estimated through the analysis of

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historical data on fish catch per unit effort or through the statistical analysis of mark-recapture experiments using tagged fish. However, these indirect methods are often biased by the selectivity of fishing gears but also by artificial on the economic ground. In addition, considerable time, and substantial efforts are required in estimating fish distribution and abundance by the statistical analysis on the historical data (Toresen *et al.*, 1998).

Following the advanced development of hydro acoustic technology, sonar, and echo sounder there have been a major impact on fisheries, especially their application in fishing system, such as searching for profitable concentration of fish. Hydro acoustic method can be considered as a suitable method for estimating fish abundance directly. In fisheries research, hydro acoustic methods have become increasingly importance over the years for studying and monitoring distribution, congregation, and migration of fish (Engas & Ona, 1987; Misund, 1987; Thorne *et al.*, 1987). However, there are some disadvantages on this method, *i.e.*, It is not be able to directly recognize fish species under study (where this aspect is important in multi species fisheries), and useful only when the fish of interest are conveniently located; they must not be too close to the surface or the bottom, where the fish echoes are obscured by much stronger reflections from these boundaries (MacLennan & Simmonds, 1992).

This paper discussed the small pelagic fish species in the Java Sea, where information derived from hydro acoustic and historical data on catch per unit of effort are used in complementary to estimate their abundance and to give comprehensive explanation on their distribution pattern, both spatially and temporally.

MATERIALS AND METHODS

Data on pelagic fish density are available from two sources, *i.e.*, from hydro acoustic survey and from records of commercial fishing. Acoustic data were collected through fishery resources survey using research vessel. Catch data were collected from big, medium, and mini purse seines, which constitute the main fishing fleet for catching pelagic fish species.

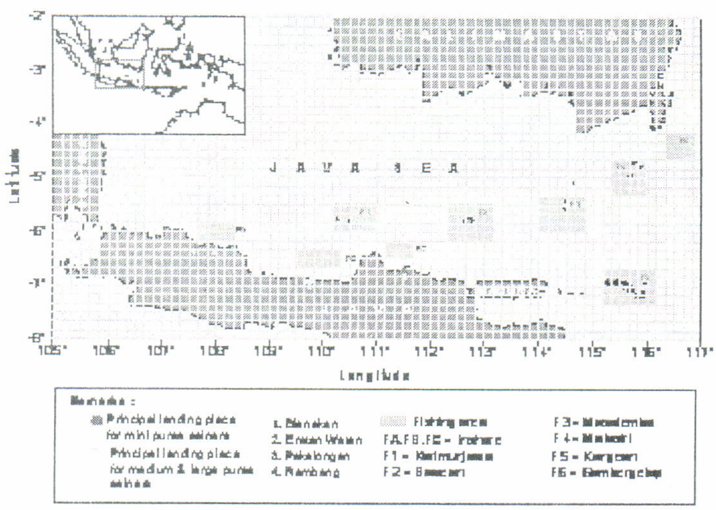

Figure 1. Geographical location of sampling sites and the main fishing areas of the fleets (purse seines).

Catch Data Collection

Catch data were collected from the records of fish catches landed by commercial fishing fleet, *i.e.* big, medium, and mini purse seines. Catch data of the big and medium purse seines represented the offshore catch, while catch data of the mini purse seines represented the inshore catch. Those two sources of data were used to describe species distribution of pelagic fish in the offshore and the inshore areas, respectively. The data were collected from their principal landing places along the north coast of Java, including Blanakan, Eretan, and Rembang for inshore catch, and Pekalongan, which is the main landing for offshore catch as well as for inshore catch (Figure 1).

Data on catch weight, fishing time, fishing ground locations, and species composition of every trip of purse seiners in the pelagic fishing fleet were recorded. Monthly data on catch by species, which were available at the port administration of sampling sites were also collected. Because the exact geographical co ordinates were often not known for fishing ground positions, they were recorded in terms of a grid system, which divides the fishing grounds into 10' latitude x 10' longitude squares.

The sampling frame is defined as the list of daily landings by seines, where the sampling unit is the sample boat. The list consists of the name of the fishing boat landed; type of boat; fishing areas; and species catch. All the purse seiners landed in the selected landing places (5 landing places) were taken as samples. The next steps, one or two sub samples (a basket of fresh fish that is *c.a.* 30 kg) are randomly taken from a fish hold of the sampling boats. The specimens were sorted by species. A comparison or crosscheck on the species composition of the sample and total catch by species from the auction was then performed.

Hydro Acoustic Data Collection

Acoustic data were collected from fishery resources survey in September until October 2002 using research vessel of R/V Mutiara IV belong to Research Institute for Marine Fisheries. Scientific echosounder Simrad EY-500, including split beam transducer system model S38-B operating at 38 KHz, was used for acquisition of the data. It was interconnected to GPS system, a Garmin GPS 45 personal navigator, to record positions and times. The acoustic data stored on the hard disk and dedicated software, EP-500, was used for processing echo signals. The echosounder system was callibrated, using a 60 mm copper sphere standard target sphere which has a target strength of -33.6 dB, according to the standard procedure (Foote et al.,1987; Knudsen, 1989; Toresen et al., 1998).

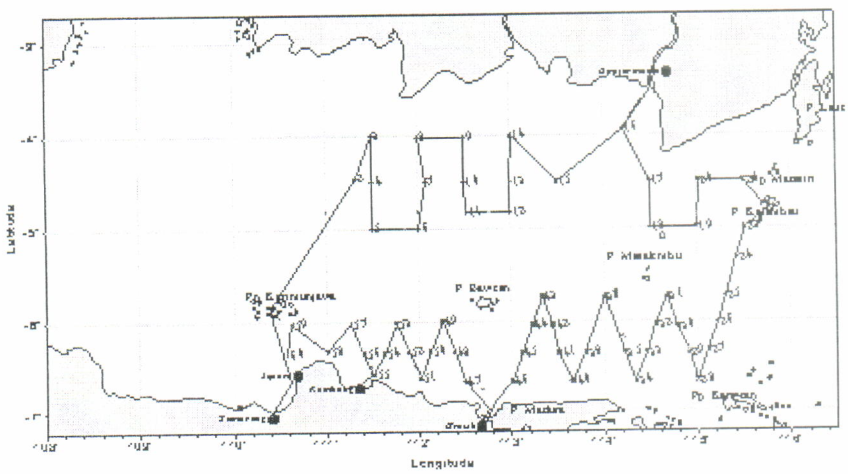

Figure 2. Tracks of hydro coustic survey in September until October 2002.

Owing to the time available and prior information that suggested the importance of central and eastern part of the Java Sea for pelagic fishery (Durand & Widodo, 1997), the survey was then devoted to cover these areas. The survey transects covered the area from the most shallow of approximately 15 m of inshore areas to the deepest of nearly 90 m of the offshore. However, although we have covered different depth zones and habitat when the study was undertaken, survey transects did not cover fishing area in the middle of the Java Sea, mainly the area around Masalembo Island, because of rough sea and limitation of time available.

Survey tracks was designed systematically in parallel transect perpendicular to the coastline in the area off south Kalimantan and triangular transect along the area off north coast of Java, with the same distance between the turning points (Figure 2). The distance between transects varied according to available time, but usually separated by 20 to 30 nautical mil (nmi) (Jolly & Hampton, 1990).

Data Analysis

Catch Data

Catch data of the pelagic fish landed by purse seines were analyzed, based on their catch per unit of effort in each fishing area. Catch per unit of effort is generally used as a standard measurement of relative abundance of fishery resources (Gulland, 1975). It is usually expressed as numbers of fish caught per unit of gear per unit of time. Freon (1980) defined the time spent to search actively the fish as the best index of effort for purse seine fisheries. However, with the available data, the number of trips and time spent at sea (days at sea) were taken to estimate the effort. Number of trips, *i.e.*, the number of trips carried out in the course of one time unit by the purse seine. Time spent at sea (days at sea), *i.e.* the effective number of days spent at sea for each trip by the purse seine. It includes the outward and return voyage between the fishing grounds and the harbors, the time devoted to search for fish, catching, and hauling them onboard.

Several selected important species in pelagic fishery were analyzed. Monthly catch per unit of effort values, either in the whole area or sectors, were used to describe seasonal variations of the species abundance. The use of these data rests on the assumption that catch per unit of effort is proportional to abundance. Interspecific species interactions, as the degree of affinity between species, was measured based on their covariations in abundance. It was examined using pearson product moment correlation. The correlation matrix was subsequently subjected to clustering and ordination for species grouping in which the analysis were done using hierarchical clustering, based on euclidean distance, and principal components, respectively.

Hydro Acoustic

Characterizing the spatial agglomeration of pelagic fish was done based on acoustic data from fishery resources survey in September until October 2002, at the time the southeast monsoon ended or the pre northwest monsoon was started to prevail. To convert the echo measurements into fish density estimates, target strength function was applied:

$$N_i = \frac{S_A}{\bar{\sigma}} . p_i . A \qquad (1$$

where:

N_i = number of fish in length group i

S_A = average integrator value allocated to a given fish species in the region of interest

p_i = proportion of a given fish species in length group i

A = area of the region being surveyed (nm^2)

$$\bar{\sigma} = \frac{\sum_i \sigma_i . p_i}{\sum p_i} \qquad (2$$

where:

σ_i = back scattering cross-section of fish in length group i, which is calculated from the target strength equation adopted for each species

As the target strength equation for the Java Sea small pelagic species was not available, empirical equation of target strength adopted from Foote (1987) was used:

$$TS = 20 \log L - 71,9 \qquad (3$$

Table1. Definition of species categories used in the official statistic and landing places data records

Statistical data record	Landing place data record	Species terms
Layang	Layang	*Decapterus russelli* *Decapterus macrosoma*
Lemuru	Siro	*Amblygaster sirm*
Kembung	Kembung Banyar	*Rastrelliger brachysoma* *Rastrelliger kanagurta*
Tembang	Tanjan, Juwi	*Sardinella gibossa* *Sardinella lemuru* *Sardinella fimbriata*
Selar	Bentong Selar	*Selar crumenophthalmus* *Selaroides leptolepis* *Atule mate* *Aleppes djeddaba* *Dussumeria acuta*
Tongkol	Tongkol	*Auxis thazard* *Ethynnus affinis*
Lain-lain	Campuran	Others

Spatial statistics, *i.e.*, Variogram and kriging methods (Clark, 1987; Millard & Neerchal, 2001) were employed to measure correlation between two observations and predicting values at particular locations that take spatial correlation into account. In the analysis, the first step was to divide the transects into 5 nmi long segments and for each of these calculate an echo integration value. The geographical position of the segments was set to their mid point. From these positions and the echo integration values, linear variogram values were calculated. Different models were tried to fit these variogram values, and the best fitting model, by means of krigging, was used to interpolate echo integration values for the entire study area. The values from the best fitting model were used to draw contour maps over the distribution of pelagic fish.

RESULTS AND DISCUSSIONS

Spatial and Seasonal Distribution of the Fish Species

A community of small and some large pelagic fishes, which are multi species in nature, are exploited by pelagic fishing fleet in the Java Sea. A total of approximately 30 pelagic species was caught (Potier & Sadhotomo, 1995). Of these, 15 species formed 90% of the total catch. Official statistical data records have grouped those 15 species into 6 statistical categories of fish catch as shown in Table 1. Nevertheless, there are different names addressed for the same species or group of species between official statistic and data records at landing places.

Seasonal abundance and distribution of each species are showed in Figures 3 and 4, which were estimated based on the catch per unit of effort and percentage of its availability relative to the total species.

Abundance of pelagic fish species exhibited fluctuation and each showing a peculiar distribution. Different species alternately dominated the pelagic resources both spatially and seasonally. *Decapterus* spp. was found to dominate the pelagic fish resources of the offshore area with the abundance much higher than the others but, in contrast, it appeared to be lesser in the inshore area.

Sardinella spp. dominated the resources of the inshore area in almost all year round with the exception of January. It was abundant in both inshore and offshore areas in November, the time when the northwest monsoon started to prevail. The species was available more in the offshore area than the inshore area in January.

Other species composed of less than 30% of the total pelagic fish resources (Figure 4). Among them were *Selar crumenophthalmus, Rastrelliger* spp., *Ambligaster sirm, Auxis thazard*, and *Ethynnus affinis, Selaroides leptolepis, Atule mate, Alepes djeddaba,* and *Dussumeria acuta*. In January, however, *Selar crumenophthalmus* dominated the resources in the inshore area whilst *Sardinella* spp. distributed more towards offshore. Another group of commercial fish, *i.e. Selaroides leptolepis*, *Atule mate*, *Alepes djeddaba*, and *Dussumeria acuta*, were found to be more abundant in the inshore than the offshore all year round. Nevertheless, their abundances have never been more than 10% of the total pelagic fish stock.

Overall, catch per unit of effort of pelagic fishes averaged monthly from 1998 to 2003 is presented in Figure 5. The figure shows trend of the catch per unit of effort both in the inshore and offshore areas, describing seasonal abundance of pelagic fish resources in the study area.

Seasonal abundance of pelagic fish resources in the inshore and offshore areas found to have similar pattern, each showing a single mode, with different trend. The abundance exhibited an increasing trend in both areas after falling down to the lowest in February, which was indicated by the lowest catch per unit of effort, *i.e.* 528.4 kg per day per vessel for the inshore area and 608.3 kg per day per vessel for the offshore area. The abundance in the inshore area has sharply increased after February, reaching to its highest in May at the time the value of the catch per unit of effort stand at 940 kg per day per vessel. At the same time, however, the abundance in the offshore area was found to continually increase and reaching a peak in September, when the value of the catch per unit of effort accounted for 1082.5 kg per day per vessel.

Figures 6, 7, and 8 show seasonal distribution and relative abundance of pelagic fish species in different fishing areas illustrated through surface plots. They are expressed as percentage of species availability (catch per unit of effort of each species) relative to the total pelagic fish stock (total catch per unit of effort). The surface plots are employed for six main pelagic fish species in six main fishing areas spreading from the central to the easternmost of the Java Sea, including the fishing areas around the waters of Karimunjawa, Bawean, Masalembo, Matasiri, Kangean, and Sambergelap.

In general, *Decapterus* spp. was more abundant in the eastern fishing areas than those in the western part. High abundance of the fish in all of the fishing areas was in August until September. In March until April, stock of *Decapterus* spp. was concentrated around the fishing areas of the southeastern most of the Java Sea (Kangean and Sambergelap), composing of more than 80% of the total catch. The stock in these areas appeared to be sharply decreased in June, leading to the condition of low abundance in almost all of the fishing areas in the Java Sea with the exception of the area around Bawean in the west (Figure 7).

Sardinella spp. made up an average of 8.4% to the total catch. Its availability was found to vary between fishing areas and seasons. However, it tends to concentrate in the fishing areas of Kangean in April and Samber in May, composing of 45 and 34% of the total catch, respectively. Other species have greater variation in abundance and distribution pattern, both spatially, and seasonally.

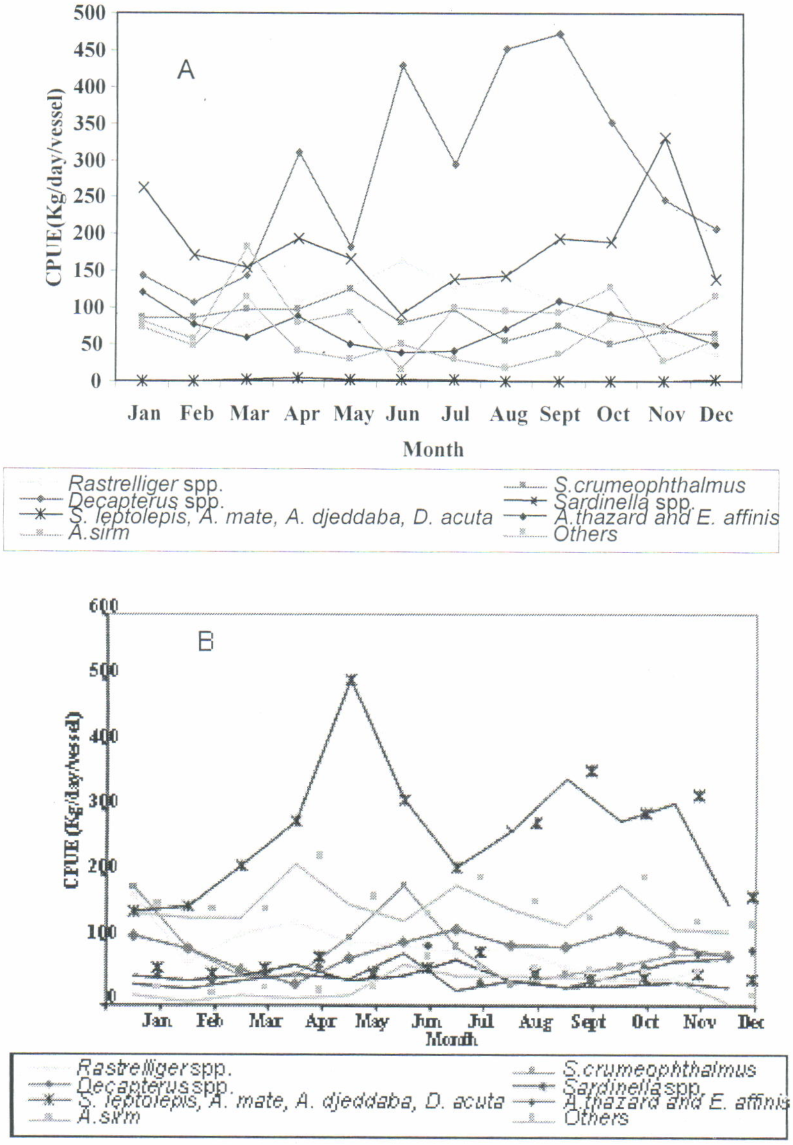

Figure 3. Seasonal variation of catch per unit of effort of each pelagic fish species within the area of offshore (A) and inshore (B), averaged from 1998 to 2003.

Matrix correlation between six species of main pelagic fishes combined from six fishing areas is showed in Table 2. It measured, through correlation coefficients, the relative intensity of interspecific covariation among the species. A positive correlation implies that for a given increase in abundance of one species, there is a corresponding increase in the other species. For a negative correlation, an increase in one implies a decrease in another. However, establishing the existence of a correlation does not imply causality.

Rastrelliger spp. exhibited a strong correlation with *S. crumenphthalmus*, *Decapterus* spp., *Sardinella* spp., and *A. sirm* ($p<0.01$). However, it had a strong positive covariation with the first three species and inversely to *A. sim.* Negative covariations were also showed between *A. sirm* and other species with different intensity. *Auxis thazard* and *Ethynnus affinis* showed a negative covariation with other species except for *Decapterus* spp. which showed a strong positive covariation indicating by significant level of correlation coefficient at $p<0.01$.

When this correlation matrix was subjected to ordination, it lead to species grouping as depicted in Figure 9. The species ordination was built based on principal components.

Rastrelliger spp., *S. crumenophthalmus,* and *Sardinella* spp. were considered belonging one group while the others were unique. This group was abundant between April and July where *Sardinella* spp. concentrated around Sambergelap and Kangean fishing areas, while *Rastrelliger* spp. and *S. cerumenophthamus* were mainly in Matasiri. The abundance tends to low in other months. Apart from this, the abundance of *Decapterus* spp. was high in August until October when abundance of *A. sirm* was low but it tends to decrease from November onward as the abundance of *A.sirm* decreased (see Figure 7 and 8). Abundance of *A. thazard* and *E. affinis* exhibited a similar pattern with *Decapterus* spp. in September but they were different in the other months.

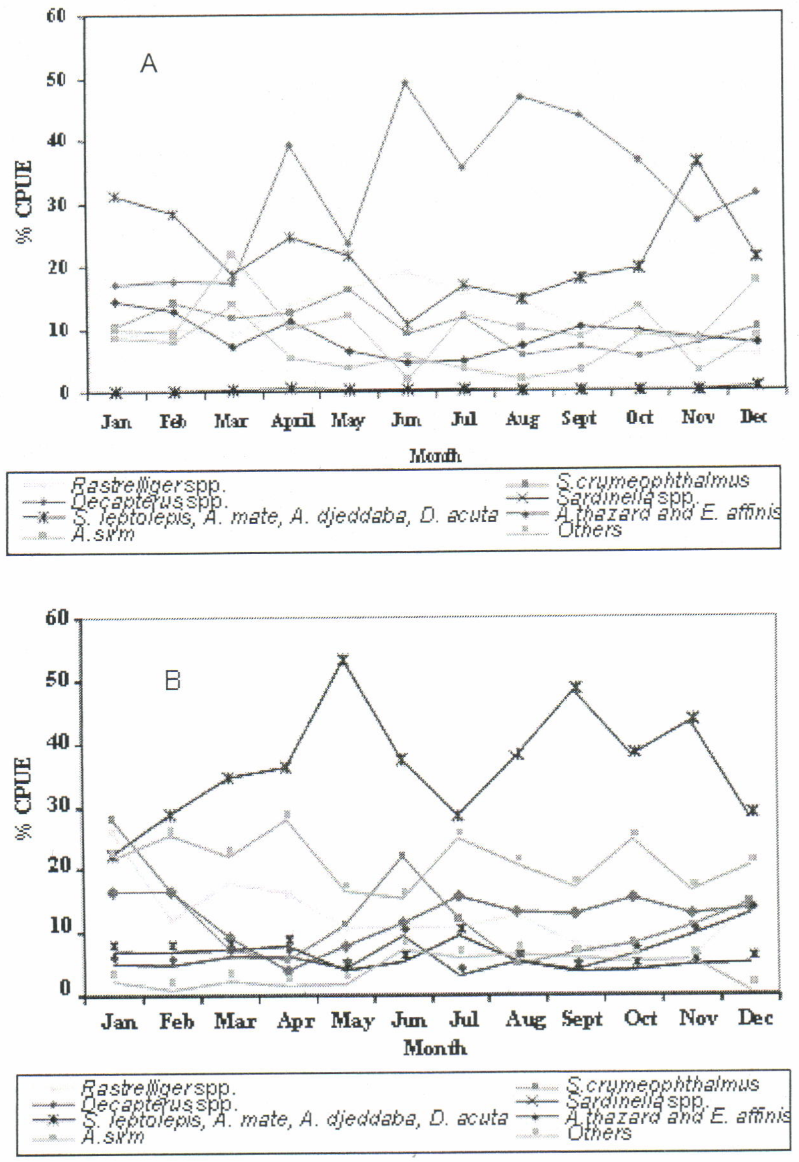

Figure 4. Percentage of catch per unit of effort of each pelagic fish species relative to the total species within the area of offshore (A) and inshore (B), averaged from 1998 to 2003.

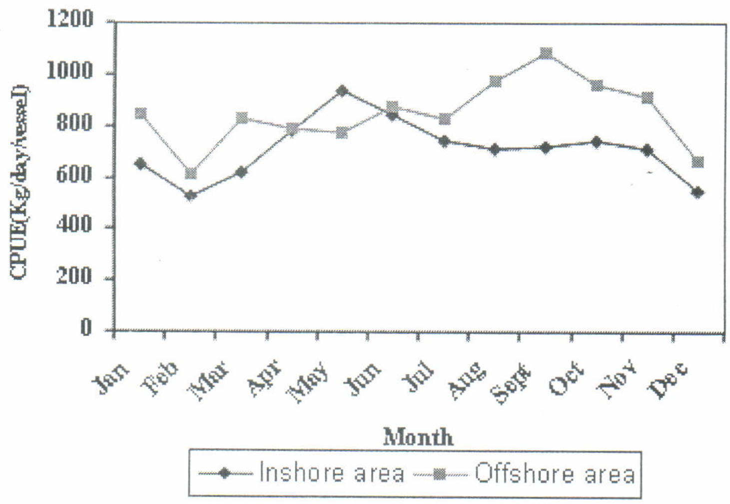

Figure 5. Trends of catch per unit of effort of pelagic fish species averaged from 1998 to 2003.

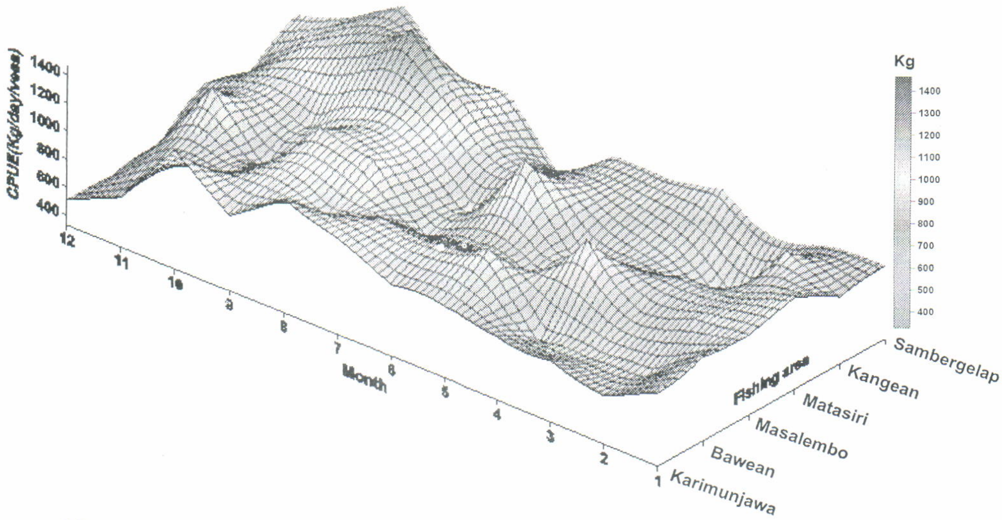

Figure 6. Map and surface plot showing the main fishing areas and seasonal relative abundance of pelagic fishes according to fishing area and season (month).

Spatial Agglomeration of the Fish

Bottom topography from central to eastern of the Java Sea is sloping toward the southeast. Along the area off south coast of Kalimantan is generally shallow waters with the depth ranged between 20 and 40 m. Taking longitudinal axis from northwest to southeast directions, the depth increased gradually and reaching the deep area of more than 80 m in the northern area of Madura Island. Meanwhile, in the eastern of the study area there was a bank that called Matasiri Bank, located in the southern of Matasiri Island with the depth of nearly 90 m.

Horizontal distribution of pelagic fish in the Java Sea in September until October is showed in Figure 10. The fish abundance is estimated from the average of every 5 nmi^2 and presented in terms of relative biomass, which is expressed as the number of fish by sector (S fish nmi^{-2}).

Figure 10 suggested that pelagic fish species tend to agglomerate and their abundance varied greatly between areas. Agglomerations of the fish were clearly showed in the western part of the study area, specifically in the northeastern part of Karimunjawa Island and southern part of Kalimantan, at the position between latitude of -4° and -5.8° and longitude of 110.6° and 113.3°. They were also appeared in the eastern part of the study area, between Matasiri and Kangean Islands, with the geographical position between latitude of -5° and -6.2° and longitude 115.1° and 115.7°. There were no agglomerations of pelagic fish exhibited in the north coast of Java during this season except in the area between Bawean and Masalembo Islands, with the geographical position between latitude of -5.7° and -6.6° and longitude of 113.4° and 114.2°.

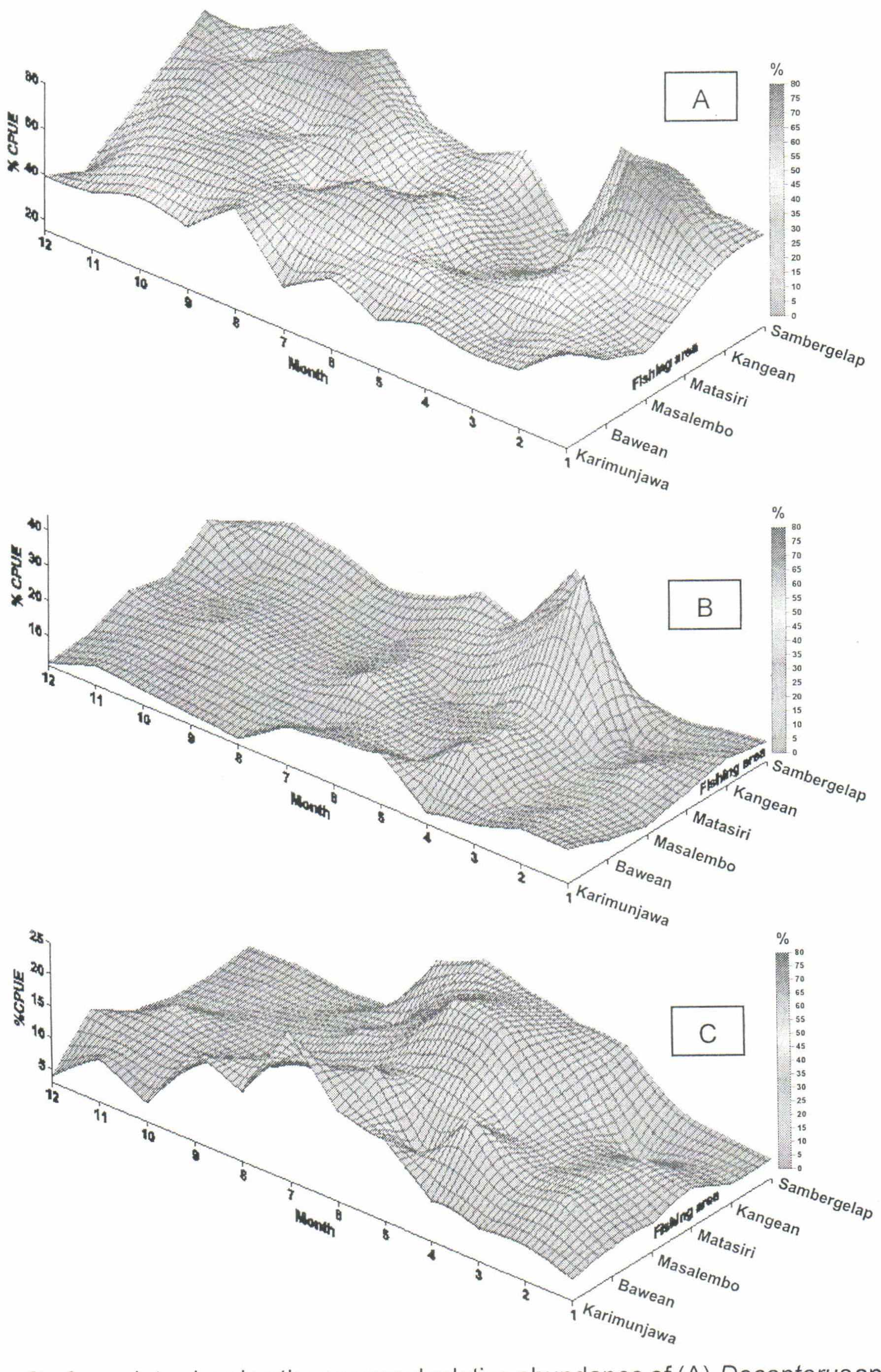

Figure 7. Surface plots showing the seasonal relative abundance of (A) *Decapterus* spp., (B) *Sardinella* spp., (C) *Rastrelliger* spp., according to fishing area and season (month).

The estimation of the relative biomass revealed that the western and northern (off south coast of Kalimantan) of the study area had a greater abundance of the resources. The density of fishes ranged between 2.60×10^4 and 255×10^4 fish nmi^{-2} with the average of 92.4×10^4 fish nmi^{-2}. The highest abundance was found in the area off south of Kalimantan, between latitude of -4.66° and longitude of 112.01°. In the eastern of the study area, between Matasiri and Kangean Islands, the abundance was considered to be moderate with the density ranged from 0.79×10^4 to 99.61×10^4 fish nmi^{-2}. The average fish density within this area was 47.65×10^4 fish nmi^{-2}. Meanwhile, in the area off north coast of Java the fishes were dispersed. The estimation of relative biomass revealed that the fish abundance over this area was relatively low, with the maximum density reached to only approximately 20×10^4 fish nmi^{-2}.

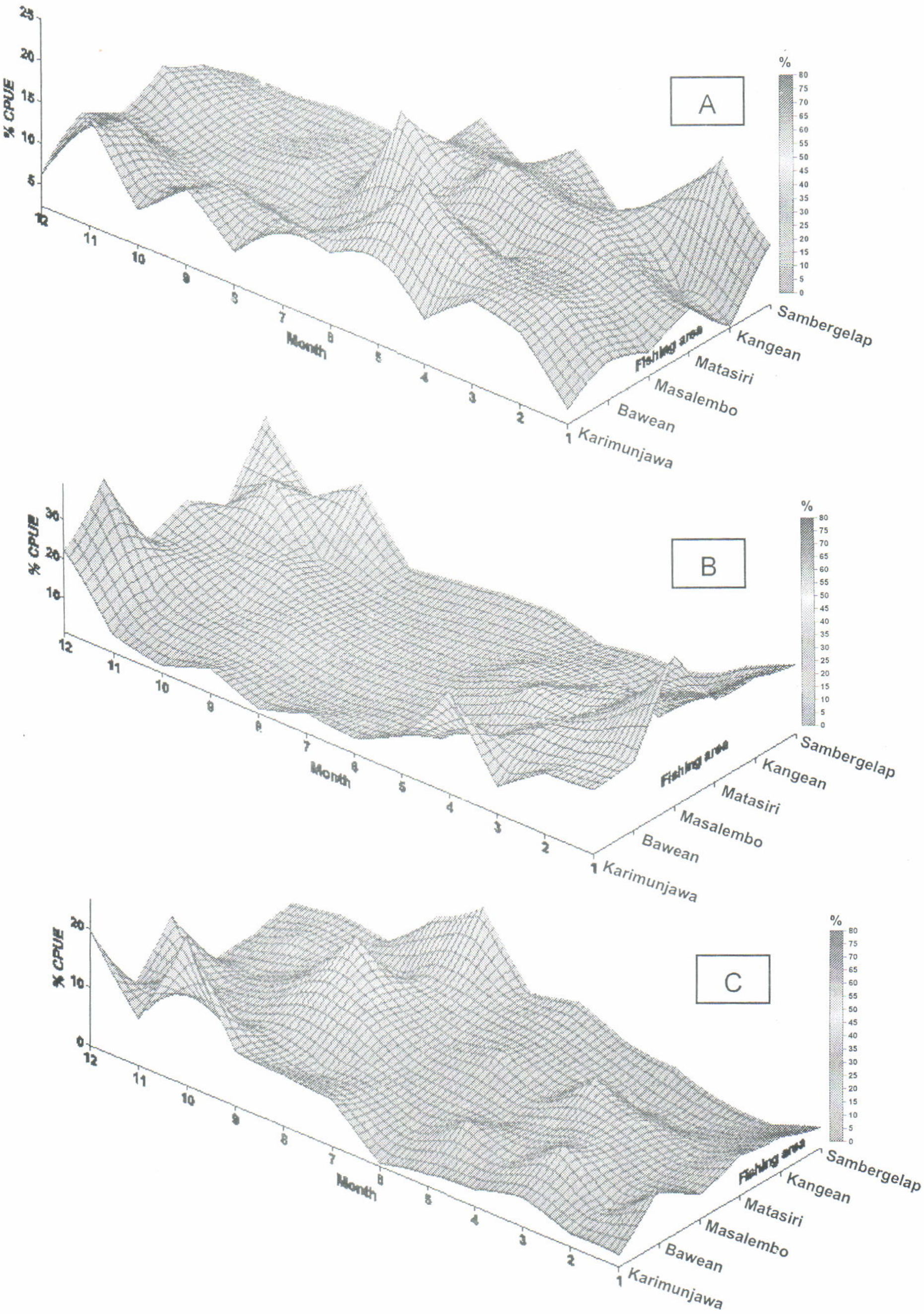

Figure 8. Surface plots showing the seasonal relative abundance of (A) *S. crumenophthalmus*, (B) *A. sirm*, (C) *A. thazard*, and *E. affinis*, according to fishing area and season (month).

Vertical cross-section of two meridional transects, north-south direction, the western and eastern parts of the survey area gave the illustration of fish distribution in different habitats during September-October (Figure 11). The meridional bottom topography of the Java Sea was clearly showed. As the sea bottom along the western transect (transect A) was nearly curve-shaped, the deepest area was in the middle with the depth of less than 60 m. While, along the eastern transect (transect B), it was more southward with the depth of more than 70 m.

Abundance of pelagic fish was found to vary greatly along the water column, but in general, the abundance tends to increase with depth, specifically those from 10 m down to 50 m deep. The fishes mostly agglomerated above the bank and sloping bottom approaching the small islands vicinity. The agglomerations of high density were found to concentrate within the depth of 30 to 40 m.

Discussion

Commercial catch rates or catch per unit of effort data have been widely used in fish stock assessment (e.g. Gulland, 1964; Kimura, 1981; Large, 1992). The use of these data rests on the assumption that catch per unit of effort is proportional to abundance. The effort is standardized in order to get representative index of the abundance. In this study, fishing day has been used as a standard of the effort and analysis of these time series catch per unit of effort data have helped us to find the fishery tendencies.

Table 2. Matrix correlation of Pearson's product moment between six species of main pelagic fishes based on their monthly average catch per unit of effort (1998 to 2002) from six fishing areas

		Rastrelliger spp.	*S.crumenoph*	*Decapterus* spp.	*A. sirm*	*Sardinella* spp.	*A. thazard and E. affinis*
Rastrelliger spp.	Correlation		.529**	.340**	-.359**	.461**	-.030
	Sig. (1-tailed)		.000	.009	.006	.000	.419
S.crumenoph	Correlation	.529**	1	.011	-.037	.239	-.064
	Sig. (1-tailed)	.000		.470	.401	.051	.332
Decapterus spp.	Correlation	.340**	.011	1	-.255**	.261*	.350**
	Sig. (1-tailed)	.009	.470		.040	.036	.007
A. sirm	Correlation	-.359**	-.037	-.255*	1	-.149	-.185
	Sig. (1-tailed)	.006	.401	.040		.156	.104
Sardinella spp.	Correlation	.461**	.239	.261*	-.149	1	-.246*
	Sig. (1-tailed)	.000	.051	.036	.156		.046
A. thazard & E. affinis	Correlation	-.030	-.064	.350**	-.185	-.246*	1
	Sig. (1-tailed)	.419	.332	.007	.104	.046	

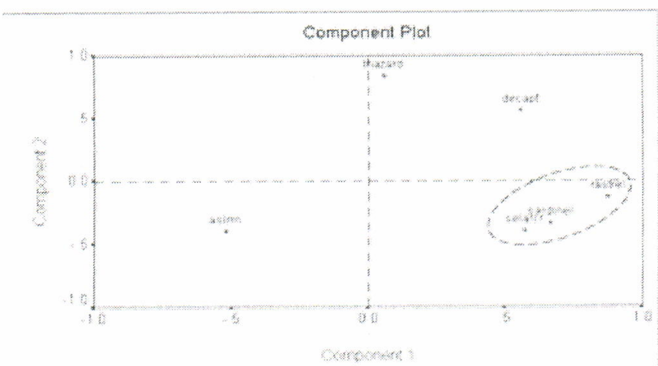

Figure 9. Species ordination, based on principal component analysis upon catch weights (monthly average catch per unit of effort 1998 to 2002), of main pelagic fishes combined from six fishing areas.

Distribution of pelagic fishes based on hydro acoustic analysis shows that the high abundance occurs in the areas around the vicinity of small islands and most of these areas are fishing grounds for pelagic fleets (Figure 11). The results of this study suggest that catch per unit of effort data collected from commercial fishery and the resource abundances data from hydro acoustic survey convey similar information, in which that variations of catch per unit of effort value between fishing areas are in accordance with the variations of resource abundances derived from hydro acoustic data. Although the commercial fishing areas do not cover the whole area of the populations, commercial fishery data can provide a cost effective way to obtain year round figures of species distribution in the Java Sea.

Abundance of pelagic fish is seasonally variable in the Java Sea, reaching its peak in May for the inshore area and September for the offshore area. The catch is mostly driven by fluctuations in the abundance of one dominant species, *Sardinella* spp. in the inshore and *Decapterus* spp. in the offshore. The two species make up the average of 36 and 32% of the total catch per unit of effort in the respective area.

The catch per unit of effort value found to be much lower in the Java Sea (1082.5 kg per day) than those in similar fishery existing in other parts of the world, e.g., Senegal and Chile (Saila, 1995). The scarcity of the resources has been revealed by the small number of fish shoals encountered during the hydro acoustic cruise. In most areas, the fishes are scattered in the water column and this spatial dispatch explains the use fish aggregating devices by fishermen, such as rumpon and light, in their fishing operations.

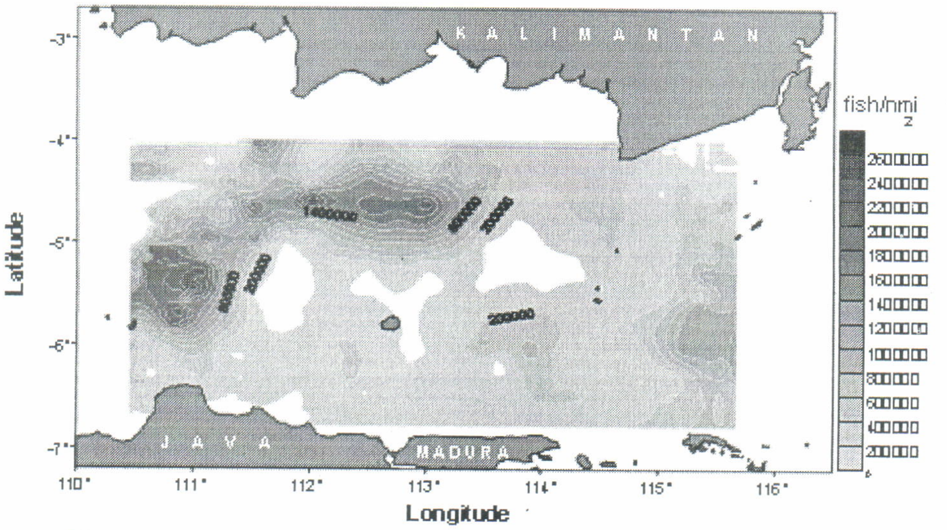

Figure 10. Horizontal distribution of pelagic fish resources within the entire water column in the Java Sea in September until October 2002.

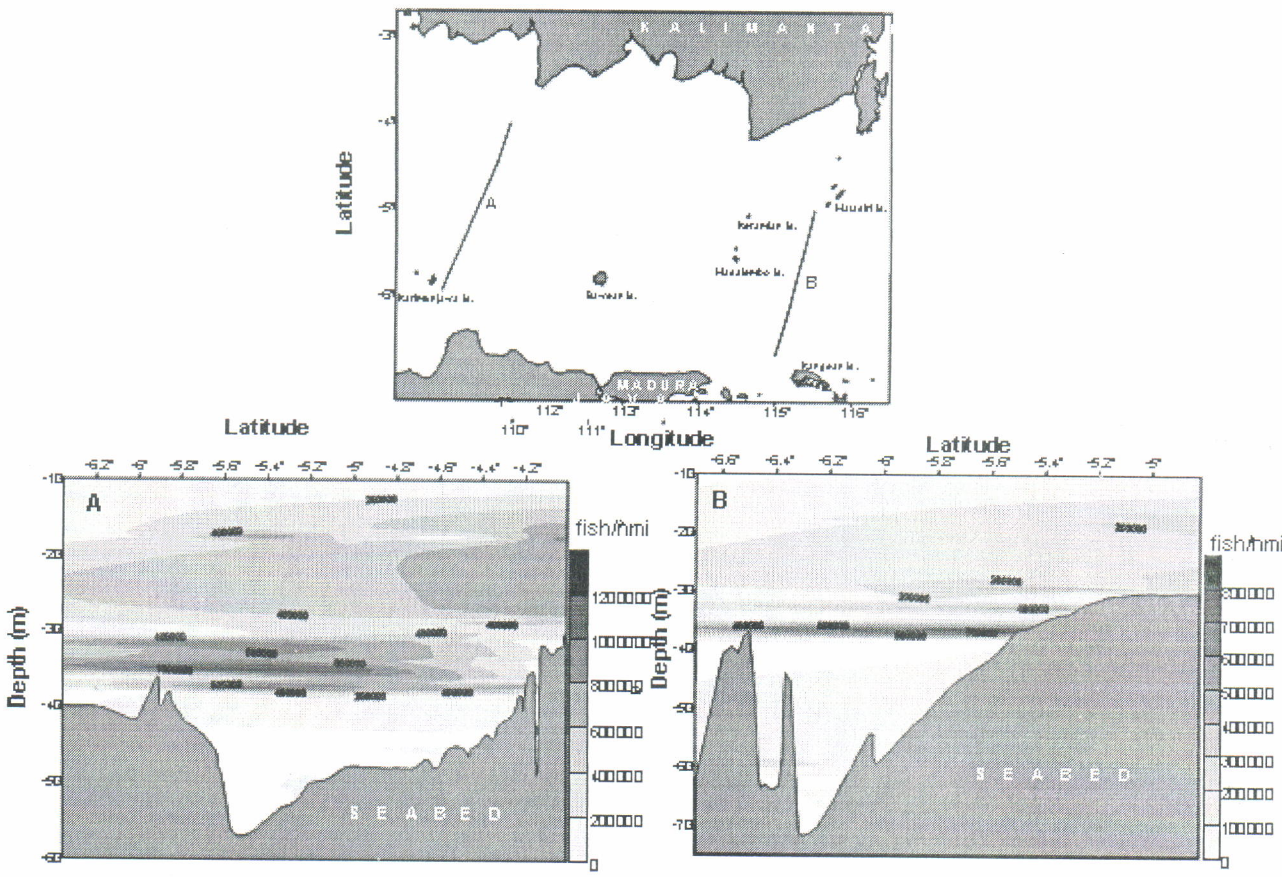

Figure 11. Vertical distribution of pelagic fish resources along the two meridional transects: (A) western part of the survey area, (B) eastern part of the survey area.

Pelagic species caught from the Java Sea are tropical species with a worldwide distribution (*S. crumenophthalmus*), Indo-pacific (*R. kanagurta*, *A. sirm*, and *S. gibbosa*) or a more restricted Southeast Asia (*R. brachysoma*, and *S. fimbriata*). Most of them are typically shoaling fish which live mostly over continental shelves and make migrations across deep waters (*R. kanagurta* and *D. macrosoma*) (Fischer & Whitehead, 1974). Their dispatch over the continental shelves is conditioned by the tolerance to salinities, some of them are euryhaline (*R. Brachysoma*, *S. gibossa*, and *S. fimbriata*) some other stenohaline (*R. kanagurta*, *D. macrosoma*, and *D. russelli*) (Pelfish, 1995).

Within any given community, there are a number of biotic and abiotic factors that influence the distribution, the abundance, and subsequently, the interactions of species. Depending on whether or not two species have similar or opposite respond to the same environmental factors, a certain pattern of interspecific covariation results. A positive covariation implies that the abundance of two species tend to increase and decrease together. For a negative covariation, an increase in one implies a decrease in the other.

The relative intensity of species covariation for the main pelagic species has been measured on the basis of their correlation coefficients. It is worth emphasizing that establishing the existence of a correlation does not imply causality. Further, the detection of a statistically significant correlation between two species abundance patterns tell us nothing about the possible underlying reasons why this may be so. However, the detection of significant interspecific covariation can be extremely helpful in generating suitable hypotheses to explain such patterns. It may also be used as a basis for generating species grouping for which it has been done in this study.

Based on the cluster and PCA analysis, *Rastrelliger* spp., *S. crumenophthalmus*, and *Sardinella* spp. were considered falling into one group while the others were unique. This group was abundant between April and July where *Sardinella* spp. were concentrated around Sambergelap and Kangean fishing areas, while *Rastrelliger* spp. and *S crumenophthamus* were mainly in Matasiri. Their abundance tends to be low in other months.

Two species of mackerels are caught from the Java Sea, *Rastrelliger kanagurta,* and *R. brachysoma*. Potier & Sadhotomo (1995) found that most mackerels represented in the catches of large and medium purse seines were *Rastrelliger kanagurta*, while *R. brachysoma* were accidentally present. On the other hand, *R. brachysoma* made up a bulk of the catch of inshore fleets (mini purse seines) in Rembang (Central Java) and Eretan (West Java), mainly between April and July (Hariati *et al.*, 1995). These imply that *R. kanagurta* distributes more offshore in the eastern deep waters fishing areas and, conversely, *R. brachysoma* distribute more inshore in the central and western shallow water of fishing areas. This phenomenon seems to confirm with ecological species related classification given by Longhurst & Pauly (1987); Widodo (1995), which grouped *R. kanagurta* and *R. brachysoma* into oceanic and coastal species, respectively.

Scads (*Decapterus* spp.) were found to be more abundant in the eastern fishing area than the western. There are two species of scads (*Decapterus* spp.) caught in the Java Sea, *i.e. Decapterus russelli* and *D. macrosoma*. Since they are grouped in one commercial category in fish landing data records, hence, impossible to give explanation with regards to the distinctive distribution pattern of the two species solely based on these data. However, referring to the investigation done during the extension of Pelfish project (1991 to 1994), it revealed that *D. macrosoma* mostly inhabited the waters of eastern part of the Java Sea and the Makassar Strait, while *D. russelli* was in the waters of Central Java and the South China Sea. Longhurst & Pauly (1987) classified *D. macrosoma* as oceanic species, while *D. russelli* was neritic species.

CONCLUSION

1. Variations of catch per unit of effort value between fishing areas derived from commercial fishing data are in accordance with the spatial variations of resource abundances derived from hydro acoustic data. This reveals that both data are able to be used in complementary to explain the spatial abundance of small pelagic fish species and to give comprehensive explanation on their distribution pattern in the Java Sea.

2. Pelagic fishery resources in the Java Sea have undergone considerable variations in both their distributions and abundances over time. As reflected by the variations of catch per unit of effort, the abundance reaches a peak in May in the inshore and September in the offshore fishing areas. It is mostly driven by abundance variability of one dominant species, *Sardinella* spp. in the inshore and *Decapterus* spp. in the offshore. The two

species make up the average of 36 and 32% of the total catch per unit of effort, respectively.

3. The catch per unit of effort value in the Java Sea is 1082.5 kg per day per vessel. The small number of fish shoals encountered in the Java Sea during the hydro acoustic cruise reveals the scarcity of the resources. Results of hydro acoustic analysis show that the high abundances agglomerate in the areas around the vicinity of small islands. However, in most areas the fishes are scattered in the whole water column and this spatial dispatch explains the use of fish aggregating devices, such as rumpon/unjam and light, in the fishing operations.

4. Based on their covariation, *Rastrelliger* spp., *Selar crumenophthalmus*, and *Sardinella* spp. are included in one group. They are abundant between April and July where *Sardinella* spp. concentrates around Sambergelap and Kangean fishing areas, while *Rastrelliger* spp. and *S. crumenophthamus* are mainly in Matasiri. Their abundance tends to be lower in other months.

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