DATA STRATIFICATION AND PELAGIC FISH DENSITY EVALUATION IN JAVA SEA[1]

D.PETIT, F. GERLOTTO, P. PETITGAS

ABSTRACT

Biomass evaluation by means of echo-integration, needs to be applied with strictness. The better will be targeted and analyzed the dominant factors acting on the area, the better will be the accuracy of estimation. A phase of descriptive observation is necessary, taking into account abiotic and biotic factors, as well as the one on species behaviour, as it can appear throughout the acoustics tool. This descriptive stage will comfort the elaboration of a stratification which will serve as a model to calculate the abundance level and its accuracy. During acoustic cruises performed from 1992 to 1994 in Java Sea open waters, various parameters were measured. Regional differences can be observed, they allow to elaborate a three areas stratification.
KEYWORDS : Java Sea, Pelagic Fish, Acoustics, Methodology, Density.

ABSTRAK

Evaluasi biomassa dengan menggunakan "echointegration" harus diaplikasikan dengan seksama. Semakin baik sasaran dan analisis terhadap sejumlah faktor dominan yang berperan di area itu, semakin akurat estimasi yang diperoleh. Diperlukan suatu pentahapan observasi deskriptif, dengan mempertimbangkan faktor-faktor biotik dan abiotik, juga perilaku jenis ikan, karena mereka dapat muncul di peralatan akustik. Tingkat deskriptif ini akan sesuai dengan elaborasi dari stratifikasi yang akan bertindak sebagai suatu model untuk menghitung tingkat kelimpahan dan akurasinya. Selama dilakukan pelayaran akustik dari 1992 - 1994 di Laut Jawa, telah diukur berbagai parameter. Diketemukan adanya perbedaan regional, sehingga memungkinkan elaborasi suatu stratifikasi 3 area.
KATA KUNCI : Laut Jawa, ikan pelagis, akustik, metodologi, densitas.

1 [1]Reprint from the Fourth Asian Fisheries Forum, 16-20 October 1995, Beijing.

To evaluate a stock of pelagic fish by the acoustic method requires a whole series of successive operations : the knowledge of the equipment characteristics and those of fish reverberation that are to be evaluated, the choice of a sampling plan depending on the geomorphology of the zone, the environmental conditions and the ones of the fishing activity. It is rare to have an ideal situation and one must always establish a selection according to the objectives, the environmental conditions and the means to be used.

Another difficulty comes up in data processing since pelagic fish species tend to have a contagious distribution because of their behaviour and most of them tend to aggregate (Gerlotto, 1993). This behaviour would not hinder the evaluations of abundance if the contagious distribution concerned the whole zone, leading thus to a stationary state. Unfortunately, environmental factors interfere in this distribution that becomes heterogeneous. It is necessary to individualize sectors where the data will be more homogenous. That is stratification. Its fitness will be all the more accurate since the borders coincide with the ones of biotic or abiotic factors which were brought to light. Thus, we understand the importance of knowing the behaviour of the stock being evaluated, but also of its environment to reach a definition of these strata. That is the reason why stratification was the point of the Akustikan 1 Workshop (Petit *et al.*, 1995) of which we present the principal results here.

MATERIALS AND METHOD

Two acoustic surveys were carried out in the Java Sea in opposite seasons : October 1993 (dry season) and February 1994 (wet season) with a dual beam echo-sounder working at a 120 kHz frequency (Fig. 1). Prospecting took place during night and day with biological sampling (pelagic and bottom trawling, or samplings on professional seiners). Fish density was integrated per nautical mile. Along the transects, Target Strength measurements (more than 10,000 echoes each) occurred. Hydrological profiles (T and S‰) were carried out in the middle and at the end of each transect.

The data used concern :

- fish density per mile in relative units,
- mean reverberation index measurements along the transects,
- number and reverberation of shoals (by analysis of echograms),
- vertical profiles of temperature and salinity by station.

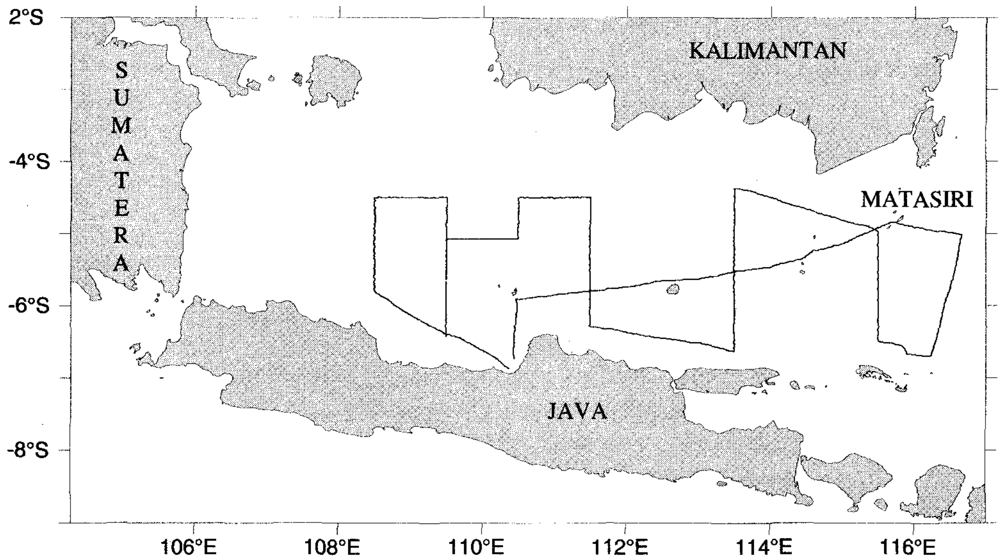


Figure 1 October 1993 and February 1994 : echointegration surveys in Java Sea.
Gambar 1 Oktober 1993 dan Februari 1994 : survei ekointegrasi di Laut Jawa.

Samplings brought little information, because the catches are low and not significant. But knowledge of commercial catches gives quite precise information on seasonal fishing sectors and above all, on the quantities and species caught.

RESULTS

Hydrological conditions

The climatic year in the Java Sea is composed of two main seasons due to the monsoon winds : a wet season (December to March) and a dry season (June to September).

During the inter-seasonal change, the conditions of the preceding season continue up until the wind currents are stable enough to bring about the reverse situation.

In the wet season, strong precipitation and outflows cause a significant desalinization of waters swept along to the East by NW winds.

In the dry season, SE winds transport waters from the East and cause the resalinization of the Java Sea.

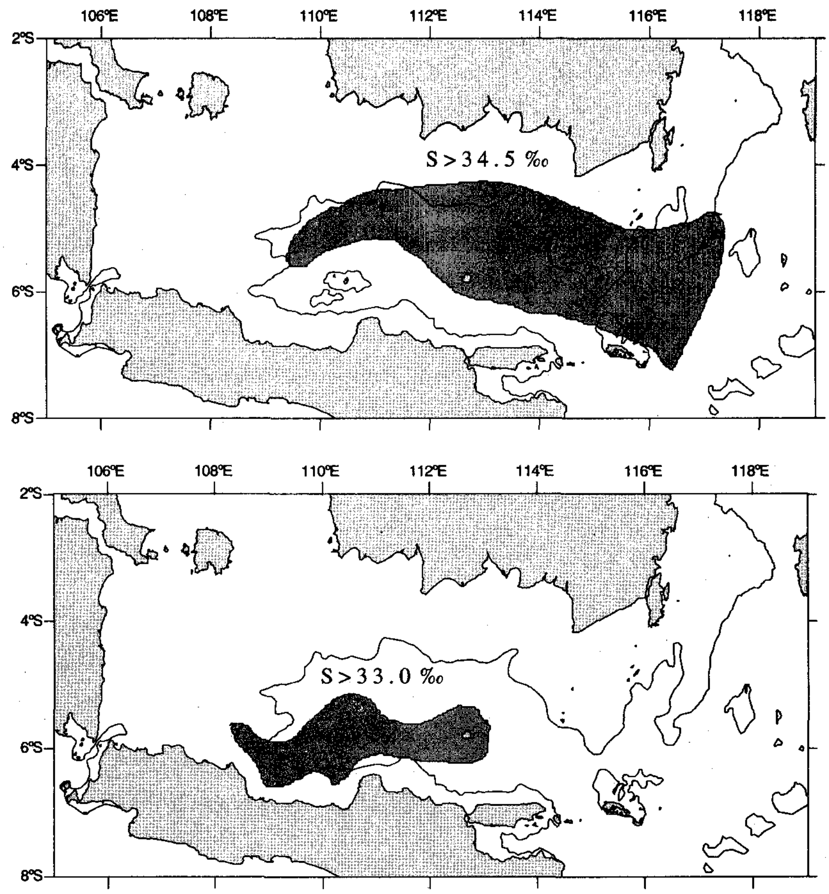


Figure 2 **Location of the mean salinity maxima in October 1993 (up) and February 1994 (down).**

Gambar 2 **Lokasi rata-rata salinitas maksima dalam bulan Oktober 1993 (atas) dan Februari 1994 (bawah).**

Average salinity maps indicate opposite seasonal situations between October and February (Fig. 2). In October, the oceanic influence is strong on the central and eastern parts, covering the deep area (more that 50 m) and the shallow zone of the Matasiri Bank. In February, the only oceanic influence is observed on the western part. There is no thermal or saline front during the two seasons.

The fishery data

Coming from another part of the Project, this information revealed that most of the seiners fishery is performed in waters with a salinity above 32‰ (Potier and Sadhotomo, 1995). The catch is twice in October than in February. The bulk of the fishery in October, is centered on the Matasiri Bank and it moves out of the Java Sea, in February. The central deep area of the Java Sea, where a permanent fishery lives along the year represents 9% in February and 20% in October of the total catch. Thus the Matasiri Bank is the most important exploited area during the oceanic influence. The fishery seems highly related to the saline conditions.

The fish densities by acoustics

There is a great difference between the acoustical densities observed by day and the ones by night. The day densities represent less than the half of the night ones, in mean value. In October, we can consider that there is a general rising gradient of abundance from West to East, there is no gradient North-South (Fig. 3). In February, there is no gradient West-East. The center of the Java Sea has densities lower than the South one. This is a North-South gradient.

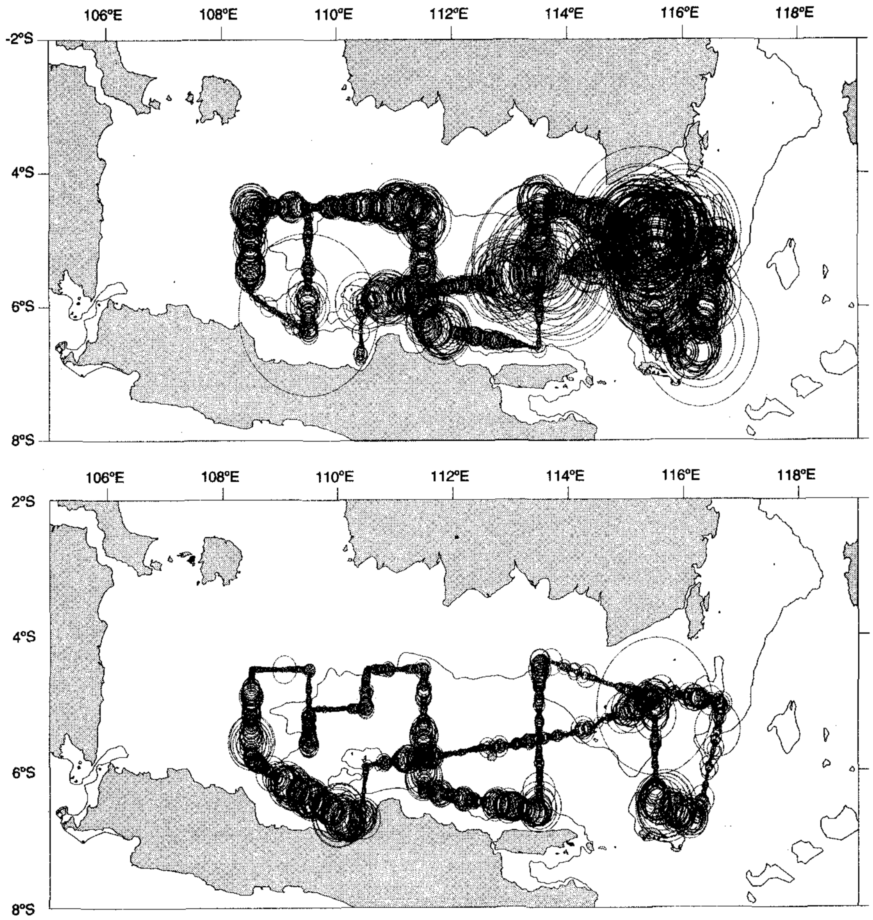
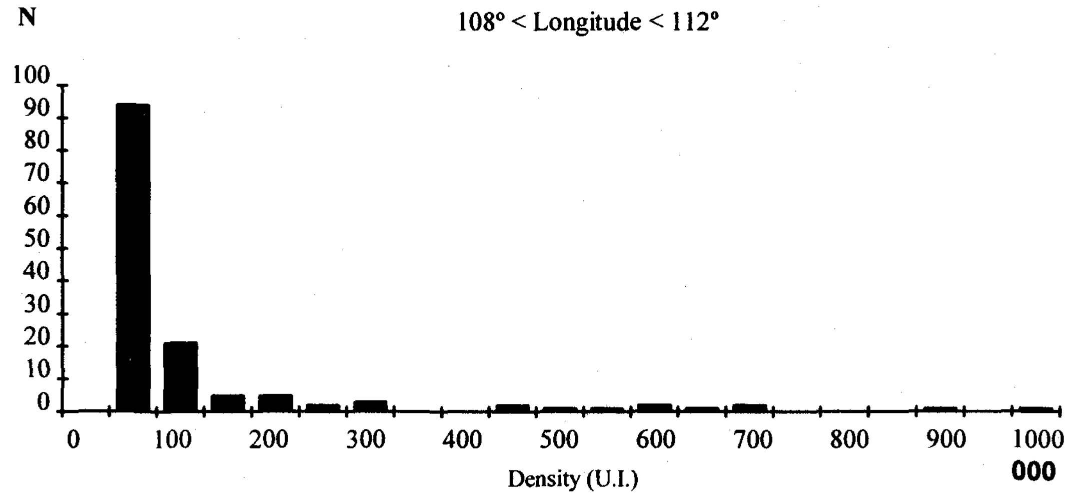


Figure 3 **Relative density of pelagic fish in October (up) and February (down).**
Gambar 3 **Densitas relatif ikan pelagis bulan Oktober (atas) dan Februari (bawah).**

The distribution of shoals

Different parameters have been measured (Nugroho *et al*, 1996). We present here only all about their location and relative reverberation. Benthic shoals are scarce and more concentrated in the eastern part (East of 114°E). The pelagic shoals are generally distributed but are more abundant, West of 111°E and East of 113°E (Matasiri Bank).The histograms of shoals reverberation have been calculated for five strata of 2° longitude large. The first mode (<100) is common all over the area; the second one (200-500) is observed in the eastern and western parts, but not between 110°E-112°E; the third one (>1000) is only present in the eastern part. A global gradient West-east is noted, the 112°E seems to be a natural border between two kinds of structure (Fig. 4).



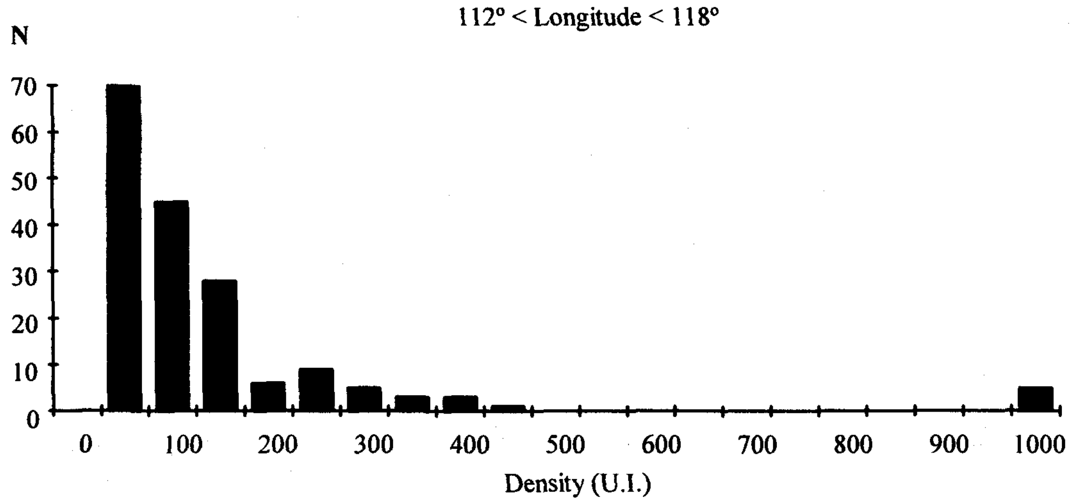


Figure 4 **Distribution on both sides of the longitude 112°E of the number (N) of fish schools according to density in October 1993 (survey 34).**

Gambar 4 **Distribusi kedua sisi dari bujur 112°T dari jumlah kawanan ikan menurut densitas dalam bulan Oktober 1993 (survei 34).**

The TS distributions

We observe that the mean TS are higher in October than in February. They are also higher in waters more than 50 m depth in the two seasons. The day-night variability seems typical of surveys : night TS are higher than day TS.

There is a trend in the fish length : the smaller are in the West of the area. There is also a trend regarding to the depth or latitude : the fishes remaining in the deep part of the Java Sea are bigger than the ones out of this area, except the Matasiri Bank in October (Fig. 5). Within the year, the fish migrate. The big fish close to the deep area or out of the zone in February, are present in a large part of the area in October. The migration could follow the movement of the salted water mass along the deep area.

The vertical distribution of density

This aspect is studied apart (Luong and Petit, 1996). The preliminary works made along a West-East transect (Semarang to Matasiri) revealed that two populations are living at the same place : the first one remains pelagic by day and night; the second one pelagic during night, disappears during the day. The density increases suddenly at around 6.00 pm and decreases at 5.00 am. Thus the horizontal layers are traversed by a population moving upwards by night. This later can be considered as semi demersal.

The spatial structure

The spatial structures have been characterized by computed variograms. The variogram is the measure of variance between points function of the distance separating them. It enables to dissect the total data variance into correlation variability occurring at various scales (Petitgas, 1991; Petitgas and Prampart, 1993).

The parameters are the sill, the maximum variability between points, and the range, the distance at which the sill is reached. It measures the average diameter of the structures. The nugget measures an heterogeneity in the spatial distribution. If high and low values are neighbouring, the nugget measures the variance associated with this discontinuity. Here the nugget is low; the local variability is low. The day and night structure are very similar. There is a small structure of 5 to 20 nautical miles. At distances longer than 50 miles, we have a trend generating an increase on the variogram (Fig. 6).

This trend is oriented West-East during October, as higher values stand on the Matasiri Bank, and it is North-South during February, because higher values are near the Java coast.

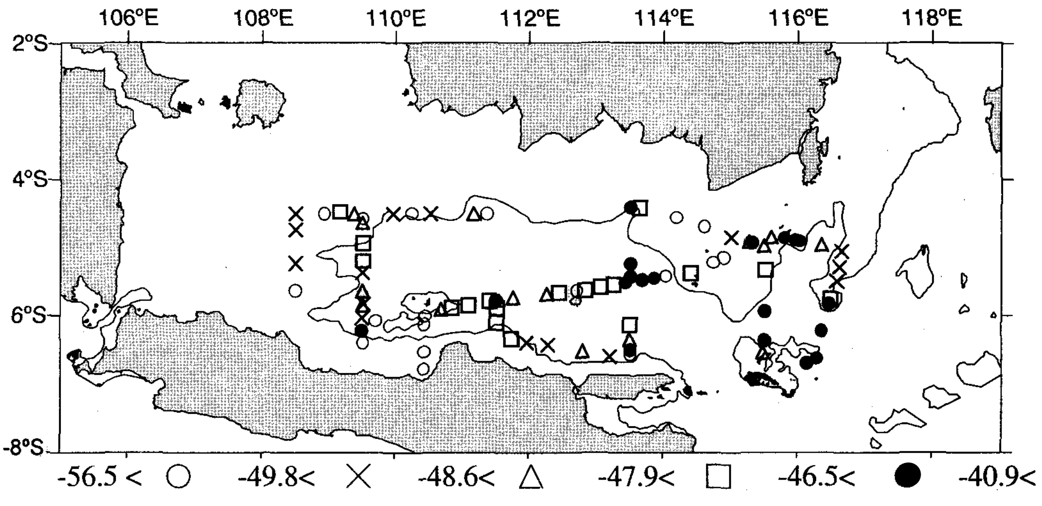


Figure 5 Distribution of the mean TS values (in dB) in October 1993.
Gambar 5 Penyebaran rata-rata nilai TS (dalam dB) dalam bulan Oktober 1993.

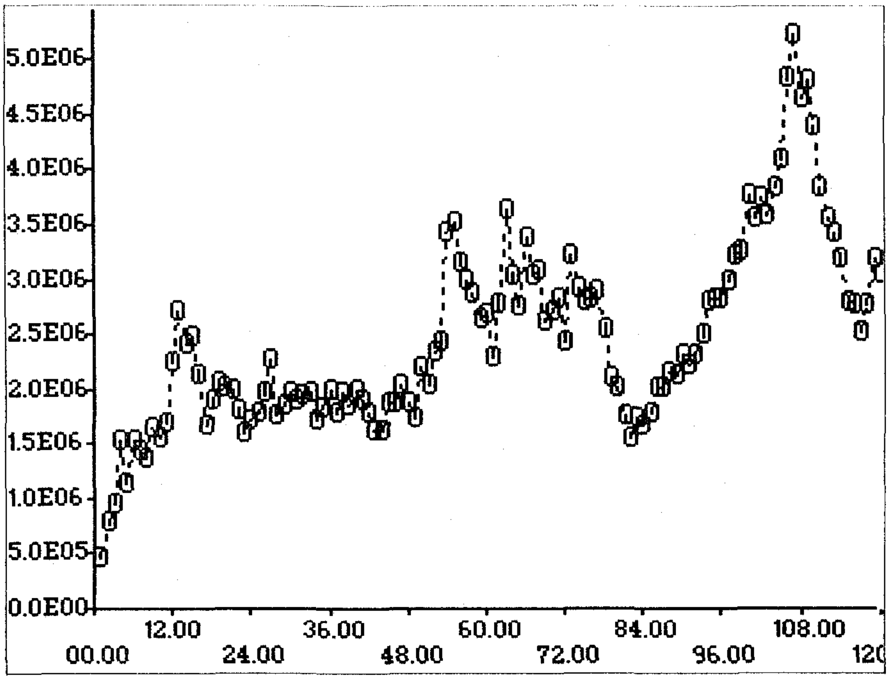


Figure Variogram on the night densities in October 1993.
Gambar 6 Variogram densitas malam hari dalam bulan Oktober 1993.

Tentative of stratification

Having this information, we can try a stratification of the Java Sea. The main interest of this, is to better describe each single stratum in term of biology and ecology of the populations and to decrease the variance in each structure[1].

Until this level of description, we can consider that 3 main populations are present in the Java Sea (Fig. 7) :

- a group (1) identified as a coastal group, recorded close to Semarang and on which very few samplings have been done. It is more apparent in wet season;
- a group (2), scattered all over the area, with a permanent kind of small structure, around 10 nautical miles, with low dispersed densities. This population is pelagic in permanence;
- a group (3) on the East, which suffers the most important part of the fishing exploitation and may migrate from the area. It is more apparent in dry season; this group would be in majority semi pelagic.

So, we can propose the following stratification (Fig. 8) :

- the stratum A, South of 6°20S, West of 114°E,
- the stratum B, North of 6°20S, West of 114°E,
- the stratum C, North of 6°20S, East of 114°E.

[1] Three others transects Semarang-Matasiri Bank which we do not report here were also used during the workshop to elaborate the stratification.

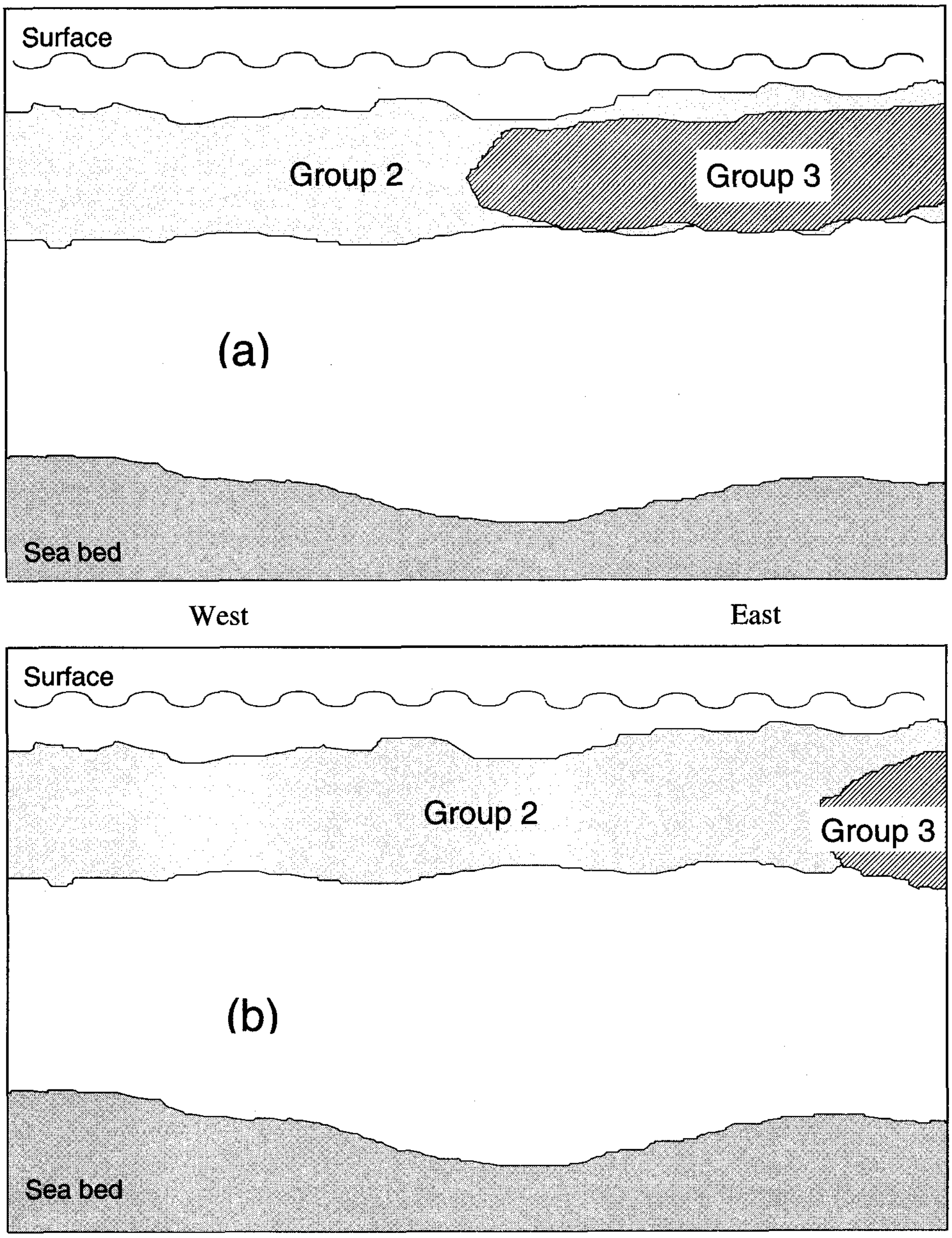


Figure 7 Group 2 and 3, night annual distribution of pelagic fish from West to East of the Java Sea : (a) October, (b) February.

Gambar 7 Kelompok 2 dan 3, distribusi malam hari dari ikan pelagis dari Barat ke Timur di Laut Jawa : (a) Oktober, (b) Februari.

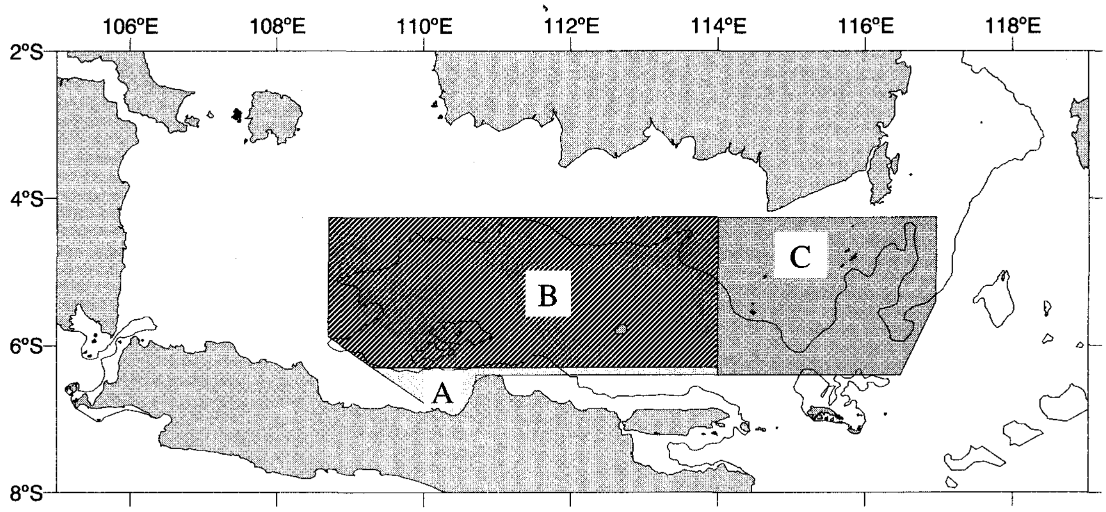


Figure 8 **The 3 strata of the Java Sea, following the location of the main fish populations.**
Gambar 8 **Ketiga strata dari Laut Jawa, mengikuti lokasi dari populasi ikan utama.**

We can test, inside each stratum, whether the distributions are more homogeneous and calculate the variograms (Fig. 9). According to the histograms of density, the stratum A reveals a net difference between the season, with a more important nocturnal density in February. The histograms for other strata in February are similar (absence of group 3). The difference between stratum B and C appears in October with big nocturnal densities into this latter (group 3). The variograms show no more nugget effect inside the strata, but the small structure (15-20 nautical miles) is observed everywhere.

DISCUSSION

The stratification is the logical way through a mean density evaluation in which subsists only the part of variance peculiar to every stratum. However, if the tentative of stratification seems to go in the sense of a personalization for every zone (histograms) it does not allow, until now, to define rigorously the geographic borders. What is the real seasonal extension for the group 3 population ? Where are the limits in the coastal zone for the groups 1 and 2 ? The coastal stratum has been under-prospected during the surveys and the structures are not precisely described there.

On the assumption that the borders are better defined, a lack of information remains about the proportion of the species living in every each stratum. The experimental catches yield too low quantities to be significant, the seiners that operate without positioning, catch all the time more or less identical proportions of species.

Taking into account the structures in the Java Sea, it is possible to evaluate the accuracy of the mean densities measured in the whole area of surveys. During the workshop, Petitgas (*in* Petit *et al*, 1995) proposed a stratification by square of 0.2 degree along the transects. The variance estimation on the whole area can be partitioned in two terms : the error made on the estimation of the squares mean and the error made on the estimation of the area mean. This later is given by the variogram of the square means. The relative error on the squares mean is then, about 15% for the day or night data.

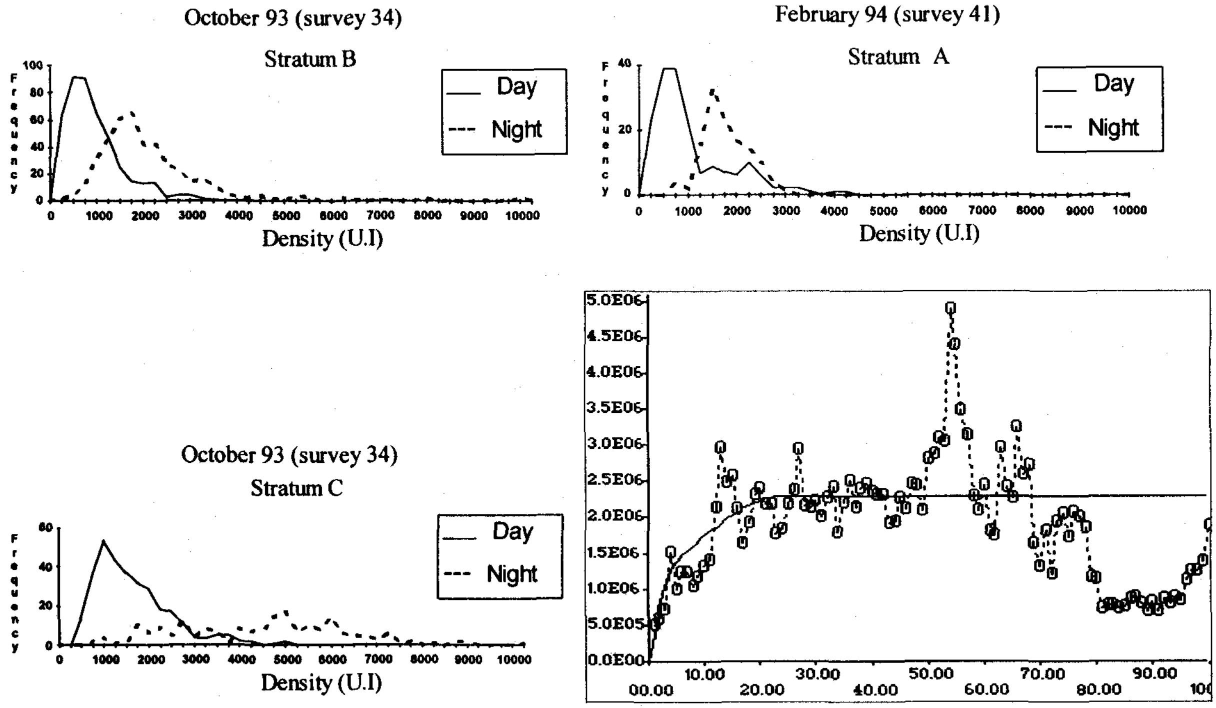


Figure 9 **After stratification, frequency distribution of densities into the 3 strata and one aspect of variograms (here, for the stratum B, night densities, in October).**

Gambar 9 **Setelah stratifikasi, frekuensi distribusi dari densitas ke dalam 3 strata dan suatu aspek dari variogram (di sini, untuk stratum B, densitas malam hari, dalam bulan Oktober).**

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DISCUSSION

(Chairman Dr. PASARIBU)

Dr. DURAND

Q : - Can you comment on the precision of the surveys performed in the Java Sea and processed during Akustikan 1 ?

Dr. PETITGAS answers : "In Acoustics, surveys have very fine resolution at small scale. At very large scale, you have important variations on the data. That happened on the data collected by the Pelfish team.

There is a trend on the data. As we have data all along the tracks, we have also small scale variations. If we look at the variograms of these surveys, we have small scale correlation and afterwards a trend. Since we were still unable to estimate the precision of the survey, we took big squares which have the correlation of small scale structure and we worked on the trend. We averaged these squares and then averaged on the total area. That is the way to estimate the precision. With this technique, the precision was around 15%. That was rather good as distances were very large."

Dr. EDDI AMIN

Q : - By using the contour line, we can get more detailed information, but the contour line itself can be made if the cruise tracks are close enough and not so far like yours. Why did you make this kind of cruise tracks ? It is not usual.

A : - I agree with you; the cruise strategy is completely different of what is usually applied. The ideal survey is to have samples as much as possible. I must specify something. You say that in order to make a contour line, we need narrower inter-transect distance. It is not completely true. We need inter-transect distance compatible with the actual distribution of the fish. Imagine fish fully distributed at random. In this case, you do not even need any track, you just take a couple of points and you obtain your mean value. If the population is geographically well delimited, you need to know the spatial model you can apply on this population. To illustrate this case, let us take one of the variograms as an example. You can see on this variogram that the model has several scales. There is one very small scale, at about 2 nautical miles. Fish is within this small structure of 2 miles meaning that, when you meet fish, the probability is high it is in a 2 mile-small area. Then, if you need to know exactly the number of small structures, we cannot do it because should have to transect every mile on such a huge area, that does not make any sense. Back to the variogram, you can see a bigger structure of 10 nautical miles. The largest distribution is around 40 to 60 miles dimension. If you apply this model, you do not need to make narrow prospecting because you will not miss any patch of fish since they have a diameter of 40 to 60 miles. So, by performing a survey with tracks separated by one degree of distance, you are practically sure that you will not lose anything. The Java Sea is exceptional if we consider the spatial distribution of fish; the trends are very low, and the structures are very large and regular. Thus, we don't need actually to make smaller inter-transect distance. It should be better, of course, because to be almost sure is less than to be absolutely sure. But statistically speaking, we can say that this kind of transect with such a large inter-transect distance, in this very particular case which is the Java Sea, fits with the distribution of the fish.

You will find other examples in Akustikan 1 papers and a lot of similar data.

Dr. FATUCHRI

Q : - How do you deal with the horizontal migration or movement of the fish ? Of the drawings depend on what kind of sampling you expect, such as one day sampling or several days. How do you deal with this ?

A : - Of course, the time variability is one of the biggest problem we have to face, at the time being, and the International Community in Acoustics will devote some effort on time variability; because, when you we go from one point to another and come back to this same point, a couple of hours later, sometimes, we find very different results. We have to deal with this time variability. In this case, the data I have shown are instant data; they are the raw data; there is no interpolation, no interpretation, they are raw data; each point is what we have seen. We are rather lucky in the case of the Java Sea, because things seem to be very smooth, variability speaking. Nevertheless, we have to deal with some characteristics, one of them is this one : let us consider that this is the West, the East of Java and the depth. This high density group seen in the East, in October, is more or less at 114 ° East Longitude. In February, it is almost outside. During the survey, we assume, we have no choice, that there is no heavy change in the distribution. Of course, we cannot compare directly one area with the other; we have another problem which is also related to day and night variability; it is a very important one; there is one group which is present in night observation and not in day distribution; that is why day density values are half of night density values. What happened ? Did the fish avoid the ship ? We do not think this is the main reason; avoidance is related to schooling which is not so important in the Java Sea. Another explanation is that the fish is very close to the bottom and therefore out of range for Acoustics or close to the surface. But, in this case, seabirds or activity at the surface would have been seen. So, the most probable hypothesis is the first one. Another group is present everywhere and we assume that one common, but with this group, we have also a problem which is a problem of discriminating what is fish and what is not fish. We have some pelagic layers, rather thick. Based on our experience in other areas, we guess that they are composed of plankton and small organisms. So, we have to know, first, what is happening with this group 3, which disappears sometimes; then, we have to split the group 2, the grey points which are fish and the coloured ones which are plankton. Fortunately, comparing day and night situations gives two different views helpful for this discrimination.

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