VERTICAL DISTRIBUTION AND CIRCADIAN CYCLE OF PELAGIC FISH DENSITY IN THE JAVA SEA[1]

N. LUONG, D. PETIT

ABSTRACT

Analyses of the acoustical data collected during several cruises made in the Java Sea from 1991 to 1994, in the context of the Pelfish project, have facilitated the elaboration of a biological model based on three groups of fish, each having particular distribution characteristics. This paper shows how analysis of bathymetric distribution on the same database gives valuable information on fish behaviour, and how this method could be used first to define different groups of fish (in our case to increase the types up to five groups) and second to raise several questions on the determinants of the fish distribution.

KEYWORDS : acoustics, behaviour, distribution, Java Sea, model.

ABSTRAK

Analisis terhadap data akustik yang dikumpulkan selama beberapa pelayaran di Laut Jawa dari 1991 - 1994 oleh Proyek Pelfish, telah memungkinkan suatu penggarapan model biologi yang didasarkan atas tiga kelompok ikan yang masing-masing mempunyai penyebaran yang khas. Makalah ini menunjukkan bagaimana analisis penyebaran berdasarkan kedalaman (batimetri) memberikan informasi yang berguna atas perilaku ikan, dan bagaimana metode ini dapat digunakan, pertama, untuk menentukan kelompok ikan yang berbeda (dalam hal ini dapat ditingkatkan sampai dengan lima kelompok), dan, kedua, untuk merangsang timbulnya sejumlah pertanyaan yang menyangkut berbagai determinan tentang distribusi ikan.

KATA KUNCI : akustik, perilaku ikan, distribusi, Laut Jawa, model.

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

The Pelfish project, a French-Indonesian cooperation and development project, started in 1991 to face up several issues converging toward the improvement of fishery management in the Java Sea (Boely, 1991). For this reason, a special attention has been given to the study of fish behaviour through 15 acoustic surveys in the Java Sea. The equipment used and the implementation of each cruise, have been previously described (Petit, 1993).

A first analysis of these data, based on a standard methodology (Gerlotto, 1993), has been used during a workshop "AKUSTIKAN I" held in December 1994 in Jakarta. A report, focusing mainly on the geographical description of the pelagic biomass distribution in the Java Sea, has been published (Petit *et al.,* 1995). One of the main results has been the elaboration of a biological model including 3 groups of fish :

- Group 1 : coastal type
- Group 2 : pelagic type, with a relative low density and an homogeneous geographical distribution
- Group 3 : quite similar as a typical oceanic community, quite dense and performing on the one hand yearly horizontal migrations to the East of the Java Sea during the rainy season (Fig. 1a) and to the center of the Java Sea during the dry season (Fig. 1b); and on the other hand daily vertical migration to the surface at night and to the sea bed during the day (Fig. 1c).

In order to validate this biological model, we have processed these data by focusing this time at the bathymetric distribution of the biomass.

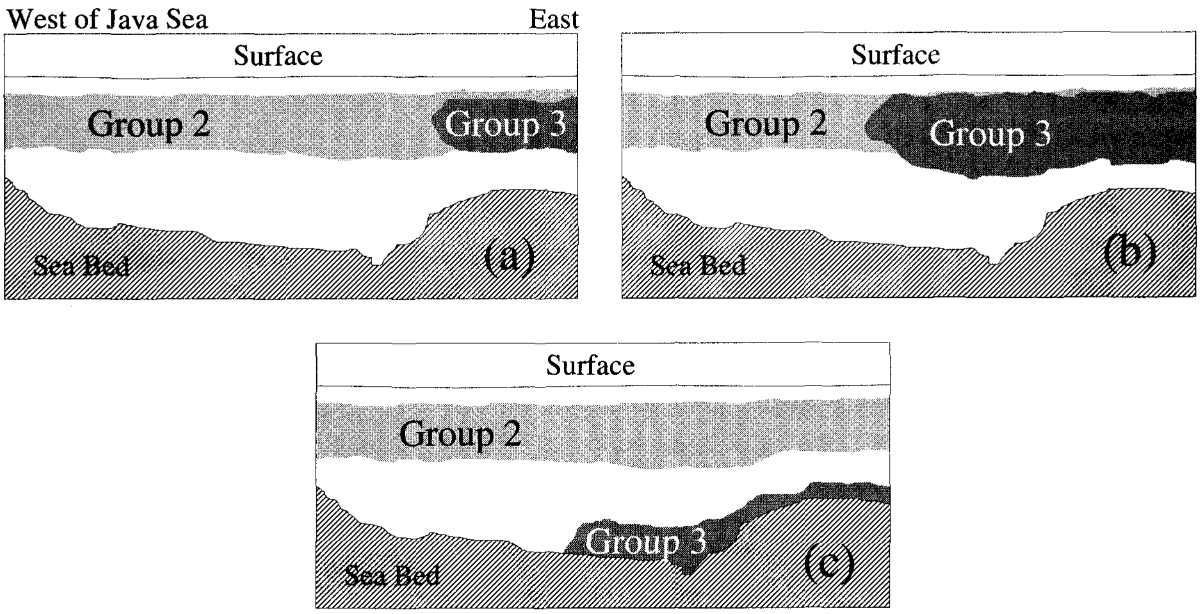


Figure 1 **Bathymetric distribution of the groups 2 and 3 according to a West to East direction in the Java Sea. (a) in February by night; (b) in October by night; (c) in October by day (from Petit *et al.,* 1995)**

Gambar 1 **Distribusi menurut kedalaman dari kelompok 2 dan 3 menurut arah Barat ke Timur di Laut Jawa. (a) Februari malam hari; (b) Oktober malam hari; (c) Oktober siang hari (dari Petit *et al.*, 1995).**

The study concerns the data of the transect from Semarang to Matasiri Islands, via Karimunjawa Island, Bawean Island and Masalembo Island (Fig. 2).

This West to East transect which shows high annual biomass variation (according to the results of the workshop "AKUSTIKAN I") seems to be a fruitful axis for studying fish behaviour in the Java Sea (Petit *et al.,* 1995). In addition, the repetition of this transect during several months (12 measures) facilitates seasonal comparisons.

Each series includes density values per nautical mile and layers of 10 m. The data processing has involved the following 4 steps :

- To facilitate descriptive analyses, we have applied a geostatistical gridding method, also called kriging method (Isaaks and Srivastava, 1989), which calculates by interpolating the relative density values for each node of a net of lines and columns previously chosen.
- This kriging realized through the use of a professional software (SURFER[2]) allows a graphic representation of the surface corresponding to the densities whose minimal value is immediately above a given threshold. This representation uses the distance covered in abscissa and the depth in ordinate. Night periods, from 6:00 PM to 5:00 AM (Petit *et al.,* 1995), have been indicated using frames (Fig. 3).
- For each of the 12 data series, several graphics of the density distribution at different thresholds have been realized (D varying from 5 to 500) (Fig. 4).
- Taking into account the previous results (Petit *et al.,* 1995), the examination of these graphics evolved to 3 directions :
    - ⇒ The study of the coastal area;
    - ⇒ The study of relative low densities;
    - ⇒ The study of relative high densities.

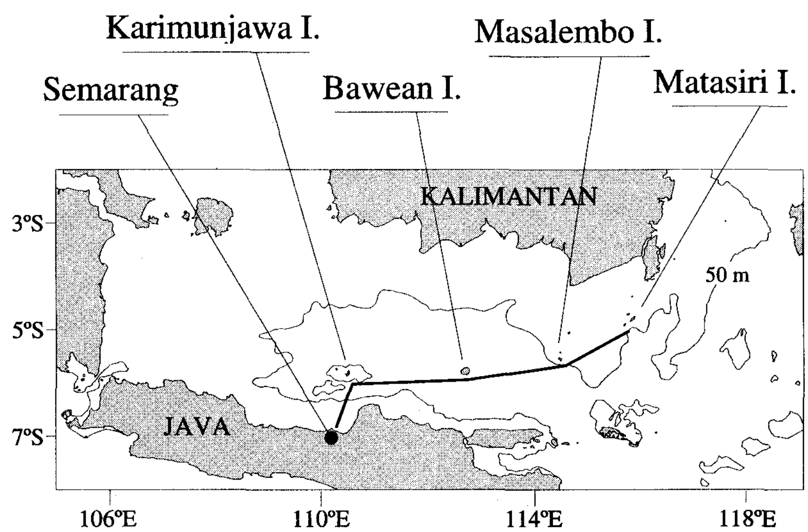


Figure 2 **Geographical location of the transect Semarang - Matasiri Island, with the position of the main islands encountered.**

Gambar 2 **Lokasi geografis dari transek Semarang - Pulau Matasiri, dengan posisi pulau-pulau yang dilaluinya.**

---

[2]SURFER Version 5.01 for Windows - Surface Mapping System Copyright ©1993-1994, Golden Software, Inc.

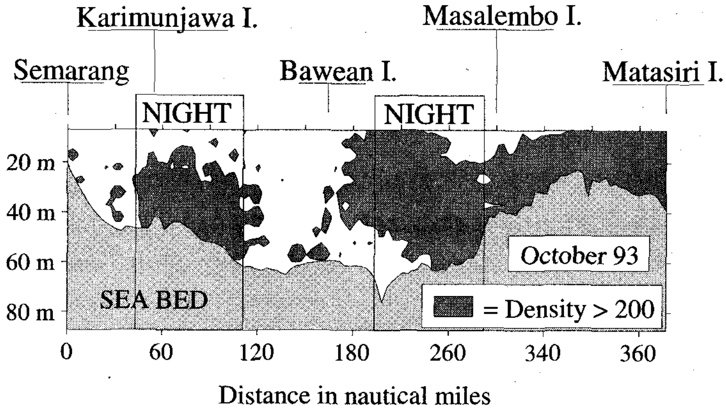


Figure 3 **Example of the representation of the density distribution in relative integration unit (r.i.u.) for a density threshold D=200. Case study : survey October 1993.**

Gambar 3 **Contoh penampilan penyebaran densitas dalam unit integrasi nisbi (r.i.u) untuk "*treshold*" densitas D=200. Studi kejadian : survei bulan Oktober 1993.**

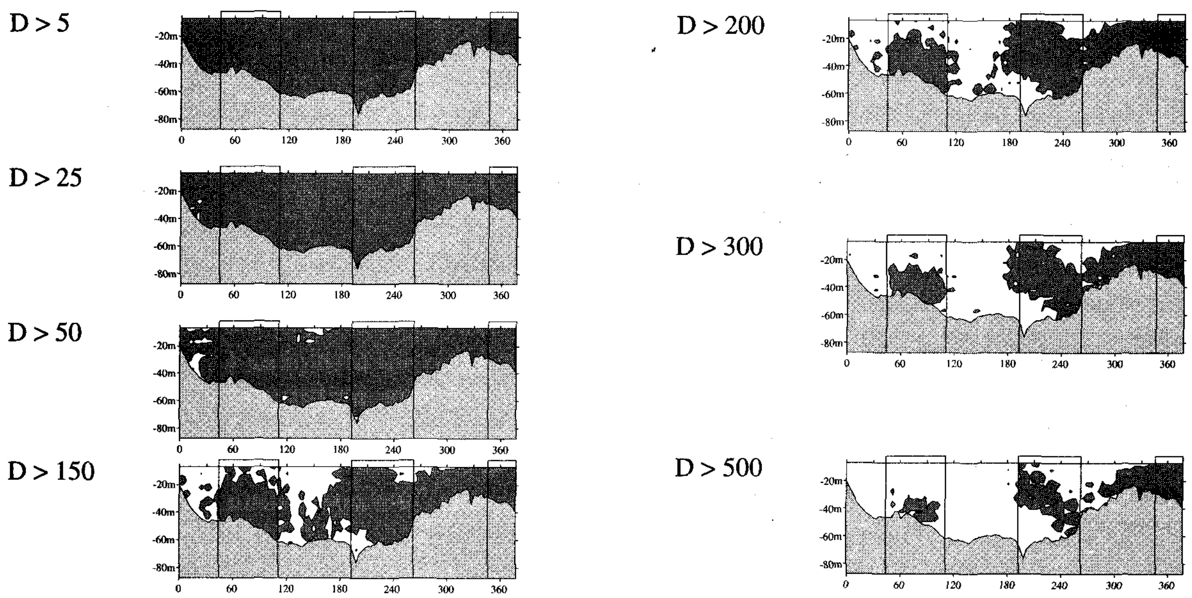


Figure 4 **Density distribution (r.i.u.) for the cruise Semarang - Matasiri Island.**

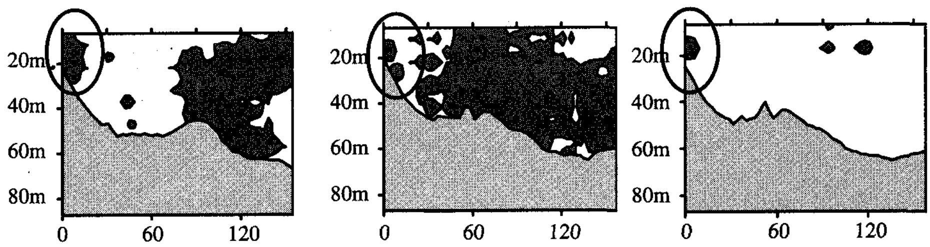
Gambar 4 **Distribusi densitas (r.i.u) dari pelayaran Semarang - Pulau Matasiri.**

Study of the coastal area

Results obtained during the day in the coastal area (up to 100 nautical miles from the coast), show clearly the existence of a group close to the coast, the density of which exceeds 100 r.i.u. (Fig. 5a). This group presents lowest density values in October 1993 (Fig. 5b) and highest in February 1994 (Fig. 5c).

This group is uniformly located at less than 30 nautical miles from the coast by day and 50 nautical miles by night. This distance varies according to the season.

Whenever it is possible to compare day and night data, the day densities are lower than the night ones (Fig. 6).



(a) Dec. 92 D > 150

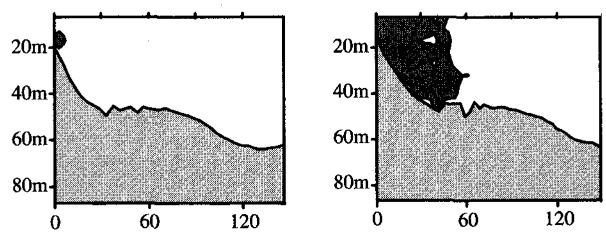
(b) Oct. 93 D > 100

(c) Feb. 94 D > 500

Figure 5 **Coastal group during different period of the year.**
Gambar 5 **Beberapa kelompok perairan pantai selama periode yang berbeda dalam setahun.**

May 92

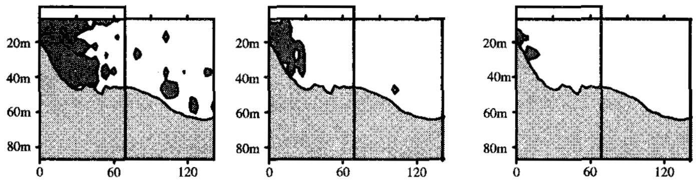
D >150



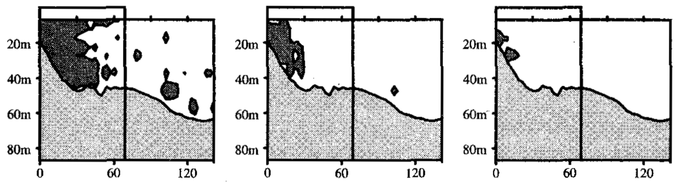
Data by : (a) Day (b) Night

Figure 6 **Comparison of density distributions by day and by night in the coastal area, for densities higher than 150 r.i.u. in May 1992.**
Gambar 6 **Perbandingan distribusi densitas siang dan malam di perairan pantai, untuk densitas lebih besar dari 150 r.i.u dalam bulan Mei 1992.**

Finally, for a given cruise and a given period of the day (day or night), the highest density values for this group are systematically those which are both close to the bottom and to the coastline (Fig. 7).



(a) Jun. 92 D > 50 | (b) Jun. 92 D > 200 | (c) Jun. 92 D > 500



(a) Jun. 92 D > 50 | (b) Jun. 92 D > 200 | (c) Jun. 92 D > 500

Figure 7 **Comparison of the coastal biomass for different density threshold values in June 1992.**

Gambar 7 **Perbandingan biomassa yang bersifat pantai bagi nilai-nilai ambang batas densitas dalam bulan Juni 1992.**

Synthesis of the coastal group

The coastal group, described in the report AKUSTIKAN I (Petit *et al.,* 1995), shows here a relative high density (more than 100 r.i.u.) with a minimum in October and a maximum in February. This group presents higher density by night than by day, which could be explained by a migration behaviour from the sea bed to the surface, and from the coast to the open sea. Nevertheless, these migrations are limited, considering that they concern only the area shallower than 30 meters and within the 50 nautical miles distance to the coast.

Study of the relatively low densities

A group with a minimal density of 10 r.i.u. is homogeneously distributed in the water column, between July and February (Fig. 8). This homogeneous group reaches up to 50 r.i.u. in October 1993.

From March, we can observe a limited decline of densities during the day between Bawean and Karimunjawa, except in the area close to the sea bed (Fig. 9a). This low density area extends in May and stretches out all around Bawean area (Fig. 9b). The average density, in this area, is lower than 2 r.i.u. In June, the reversed phenomenon occurs and leads to a situation quite similar to that observed in March (Fig. 9c).

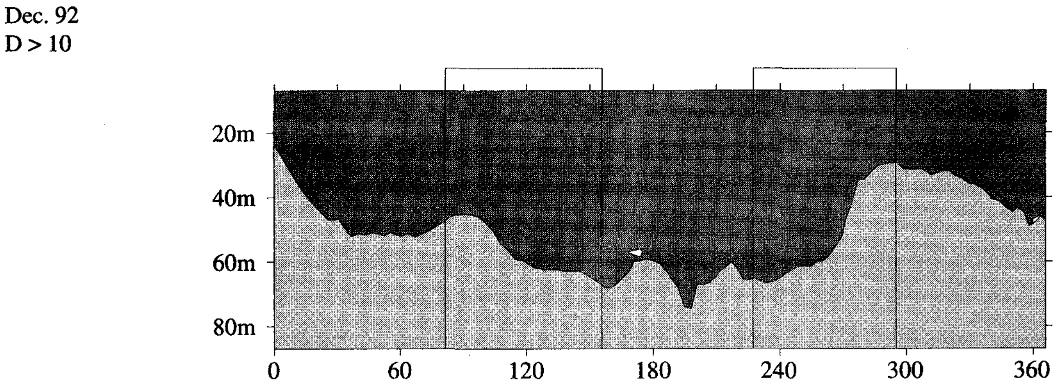


Figure 8 Distribution of the densities above 10 r.i.u. between July and February.
Gambar 8 Distribusi densitas di atas 10 r.i.u antara bulan Juli dan Februari 1992.

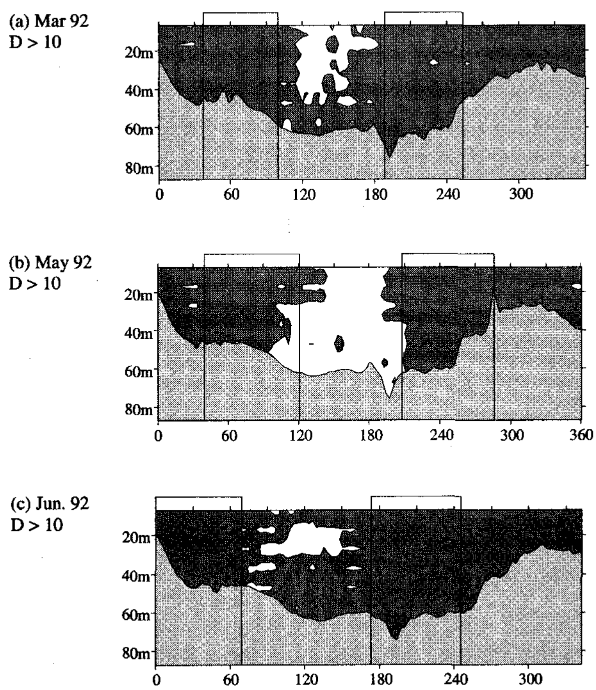


Figure 9 Distribution of density, at least of 10 r.i.u., between March and June 1992.
Gambar 9 Distribusi densitas, paling tidak 10 r.i.u., antara Maret dan Juni 1992.

Synthesis of the relatives low densities

The group of relative low densities could correspond to the pelagic group which presents an homogenous horizontal distribution as described in the report AKUSTIKAN I (Petit *et al.,* 1995). Nevertheless it appears that this homogenous distribution only occurs during a part of the year, from July to February. During this period there is no clear pattern of vertical or horizontal migrations. In March, this group seems to vanish during the day, in the area from Karimunjawa to Masalembo. That phenomenon, more obvious in May, decreases in June.

Study of the relative high density group

Almost non-existent in March (Fig. 10a), high densities, higher than 200 r.i.u., appear in May, in the Masalembo area (Fig. 10b); then in June between Bawean and Matasiri (Fig. 10c). From October to December these high densities can be found at night all the way to Karimunjawa (Fig. 10d, e). Then, in February, these high densities vanish again, except in the East of Matasiri, and in the East of Karimunjawa (Fig. 10f).

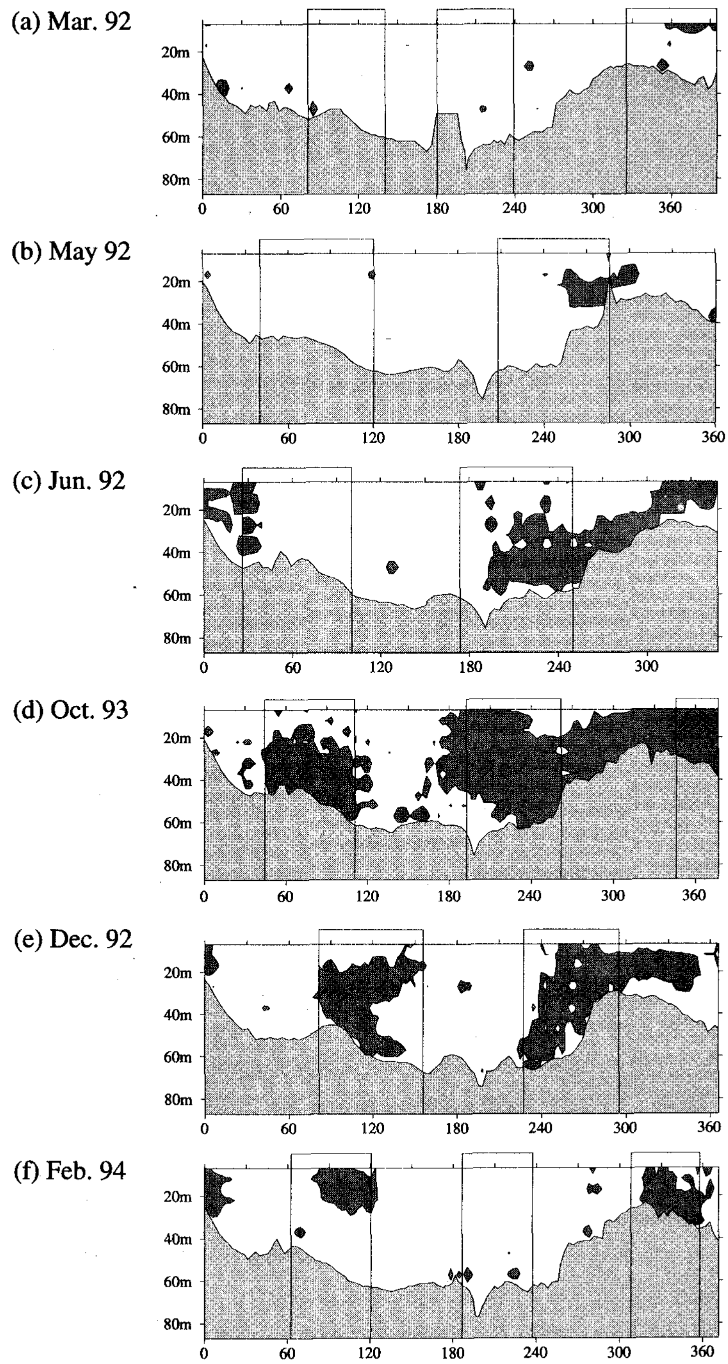


Figure 10 **Comparison of the distribution of the high densities (higher than 200 r.i.u.) during different periods of the year.**

Gambar 10 **Perbandingan distribusi densitas tinggi (lebih dari 200 r.i.u) selama periode yang berbeda dalam setahun.**

The observation of the bathymetric distribution of these high densities allows to distinguish 3 different subgroups :

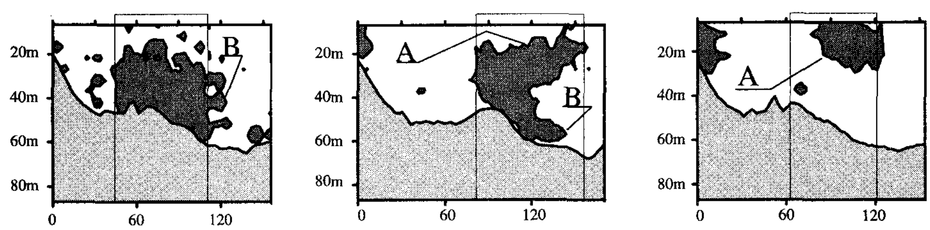
- during the day, observations show the presence of high densities in the shallow water area (Masalembo - Matasiri). These high day densities which could not be found in the area of deep water (Karimunjawa -- Bawean), characterize a subgroup living in the East area of the Java Sea up to Masalembo which never goes more westward;
- at night, in the deep area we can observe part of the high densities close to the surface and totally away from sea bed (Fig. 11c), while another part of the densities does not go up to the surface and stay in contact to the sea bed (Fig. 11a). This difference of bathymetric distribution characterizes 2 subgroups which may coexist during part of the year (Fig. 11b).

Synthesis of the relative high densities

We can notice a migration of the relative high densities from the East to the centre of the Java Sea. The migration starts at the beginning of May, reaches its maximum between October and December and then disappears in February.

This group seems to be divided in 3 subgroups :

- the first one presents high densities, both by day and by night. It is restricted to the shallow area which stretches from Masalembo to Matasiri. It appears in March, and vanishes in February;
- the second group, not detectable by day, goes up from the sea bed during the night without reaching the surface. This group appears during June in the shallow water of Masalembo and Matasiri Islands and spreads considerably up to October from there to Karimunjawa Island. Still present in December, it seems to disappear in February, except in the East of Matasiri;
- the third one is not detectable by day. It leaves totally the sea bed at night, and goes up, close to the surface. It arrives around June from the East of the Java Sea, stretches to the West until December, and leaves the Java Sea in February, except in the area of Karimunjawa.



(a) Oct.93 (b) Dec. 92 (c) Feb.94

Figure 11 **Subgroups from Karimunjawa to Bawean by night (thres. : 200 r.i.u.) :**
- group A goes up to the surface
- group B stays close to the sea bed.

Gambar 11 **Sub kelompok di antara Karimunjawa dan Bawean pada malam hari (*ambang*: 200 r.i.u) :**
- A. Kelompok yang bergerak ke permukaan
- B. Kelompok yang tinggal dekat dasar laut.

CONCLUSION

The large amount of information given by the study of the bathymetric distribution allows to improve or modify the knowledge previously obtained through the study of the geographical density distribution (Petit *et al.*, 1995). The main modification is the division of the oceanic type of the biological model proposed in the report made after the workshop AKUSTIKAN I, in 3 subgroups. Each of them has a different bathymetric distribution and presents a different seasonal variation. Furthermore, night phenomena of vertical migration, described in the same report, could be observed for each of the 3 groups but more or less clearly as it has been previously said.

According to the results of this vertical distribution study, we know that fish population of the Java Sea can be divided in 5 groups, with particular distributions characteristics (one group of coastal type, one group of pelagic type and 3 groups of oceanic type). The exploitation of these results, in parallel with other kinds of observations (experimental catches, species composition in landing sites, evolution of the temperature, salinity and current of the water,etc.), could allow us to characterize these groups in term of species, and to understand the determinants of the vertical and horizontal fish distribution.

REFERENCES

Boely T., 1991. Work plan 1990-1994. ORSTOM, Paris.

Gerlotto F., 1993. Rapport de mission à Jakarta (14/11/93-4/12/93). Protocole de traitement et d'analyse des données acoustiques de la mer de Java. Pelfish Report, 31 p.

Isaaks E.H. and Srivastava R.M., 1989. An introduction to applied geostatistics. Oxford University Press, New York, 561 p.

Petit D., 1993. Rapport d'activité sur les travaux effectués en acoustique dans le cadre du Projet "Java Sea Pelagic Fishery Assessment Project". Report, 38 p.

Petit D., Gerlotto F., Luong N. and Nugroho D., 1995. AKUSTIKAN 1. Workshop Report, Ancol Jakarta : 5-10/12/1994. Java Sea Pelagic Fishery Assessment Project, Sci. and Tech. Doc., 21 : 117 p.

DISCUSSION

(Chairman Dr. WIDODO)

Dr. ILAHUDE

Q : - In October 1993, you had higher density (high salinity) than in March (low salinity). Do you agree with the hypothesis that fish is driven out from the Java Sea or is coming into, following the in and out of the oceanic waters ?

A : - If we look at the evolution of the salinity, we can see a decrease during the West monsoon (wet), because of the water discharge of the Barito River. The salinity decreases mainly in this area, like a peak which goes from the South to the North. If you look, in the same time, at the evolution of the low density, we see that there is a gap between Karimunjawa and Bawean while the low salinity is not present. Salinity has a very important effect on the fish density but maybe there are other reasons and parameters which interact with the salinity that could explain the poorness of the populations.

Dr. MERTA

Q : - If we look at Figure 1, about these three groups, Group 2 seems to be stable at day and night. It means that fishermen could fish this group any time, at night or day time. It is not the same for the third group because it moves down to the bottom during the day, and comes up at night. My question is : could you give us more explanations about theses two Groups 2 and 3 ? What species are Groups 2 and 3 composed of ?

A : - This model has been conceived after the workshop Akustikan 1. It was based on the hypothesis of the existence of 3 acoustic populations. We speak in terms of acoustics populations, not in terms of species populations. Each group represents all the populations of fish, all kind of species which present the same behaviour according to their location within the water and the Target Strength measurements. Therefore, it is difficult to say, using this tools, what kind of species is here and there. We may guess after having described different kinds of acoustical populations and after sampling from fishing catches in a precise area. We can apply the results where we meet this group or that one. In any case, we need to have catch data to get information on the species. Sampling from the big purse seiners, operating at night, using attractive device, may also be biased. It is likely that the gears used by these fleets are selective and only catch fish from the population 3, not from the Group 2.

Mr MUNANDAR

Q : - I would like to know the model you used to calculate the vertical distribution of density and the validation of this model whose confidence limit must be known.

A : - I applied software such as SURFER, which uses geostatistical gridding method. This gridding calculates all the densities through interpolation at the knot of the net of lines and columns which have been previously chosen. The important point in this method is that we must be sure we are allowed to interpolate densities between two points. During the Akustikan 1 workshop, with another software called EVA, we found there was a structure lesser than 1.5 Nautical mile. That means that 2 points separated by less than 1.5 nm are directly correlated. Based on this hypothesis, we decided to interpolate using this value.

ISBN No. 979 - 8186 - 64 - 8

PROCEEDING OF ACOUSTICS
SEMINAR AKUSTIKAN 2

Bandungan 27th - 29th May, 1996

European Union

Central Research Institute for Fisheries
Agency for Agricultural Research and Development
Ministry of Agriculture

French Scientific Research
Institute for Development
through Cooperation