

TENTATIVE RELATION BETWEEN ACOUSTICS AND DYNAMICS. A CASE STUDY : THE PURSE SEINE FISHERY OF THE JAVA SEA¹

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ABSTRACT

The purse seiners of the Java Sea use light and Fish Aggregating Devices (FAD) to catch the fish. The use of such fishing device invites questions on the relation which can exist between fish and the fishing vessels.

The use of acoustic cruises on fishing grounds, linked with the location of fishing vessels, can give us a first knowledge of such relation.

In the Java Sea, it seems that the fishermen are able to detect fish concentrations, even though close to the bottom. They increase a natural phenomenon which is the rising of this fish population at night. With the lights, they seem to alter the distribution of the fish within these concentrations, in order to aggregate it around the vessels and to catch it.

KEYWORDS : fishing operation, acoustics, spatial structure, pelagic fish, Java Sea.

ABSTRAK

Purse seine di Laut Jawa menggunakan cahaya dan alat bantu rumpon untuk menangkap ikan. Penggunaan alat bantu penangkapan tersebut menimbulkan pertanyaan tentang hubungan antara ikan dan kapal-kapal ikan. Pelayaran akustik pada daerah penangkapan dengan lokasi di sekitar kapal-kapal penangkap dapat memberikan pengetahuan awal tentang hubungan tersebut.

Di Laut Jawa nelayan dapat menentukan kumpulan ikan walaupun berada di dekat dasar perairan. Mereka menggunakan fenomena alam dimana populasi ikan akan bergerak kepermukaan pada malam hari. Melalui penggunaan cahaya mereka mengubah penyebaran konsentrasi ikan agar berkelompok disekitar kapal kemudian ditangkap.

KATA KUNCI : operasi penangkapan ikan, akustik, stuktur spasial, ikan pelagis, Laut Jawa.

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As most of the Asian pelagic fisheries, the purse seine fishery of the Java Sea uses Fish Aggregating Device (FAD) and light to attract the fish.

Introduced in the seventies, the seine net has replaced the *payang* (Danish seine), the traditional fishing gear of the Javanese fishermen. During the first stages of the fishery, the fishing tactics, applied by the seiners, remained the same as the *payang* one (Fig. 1).

On the fishing ground, they laid 10 to 15 *rumpons*² and watched on the aggregation of the fish around them. Every night they settled around the *rumpons* where the fish was the most abundant. The presence of fish near the *rumpons* was detected by the view of fish schools at the surface just before dusk or by the catch of fish with handlines close to the raft. Just before setting, paraffin pressure lamps were put at sea as a help to concentrate the fish under the *rumpons*.

In 1985-1987 electric lamps and radio were introduced in the seine net fishery (Potier and Petit, 1995). Both tools have induced great changes. They have increased the mobility of the vessels which have become able to prospect more than one fishing ground during a trip and to follow the fish concentrations.

Most of the concentration is induced with the electric lamps. The *rumpon* is only used to maintain the fish around the fishing vessel during the night.

Such fishing tactics set the question of their use. Are the fishing vessels able to find fish concentrations and alter them to catch the fish? Or, do they initiate the aggregation of the fish, this latter scattering in the water column?

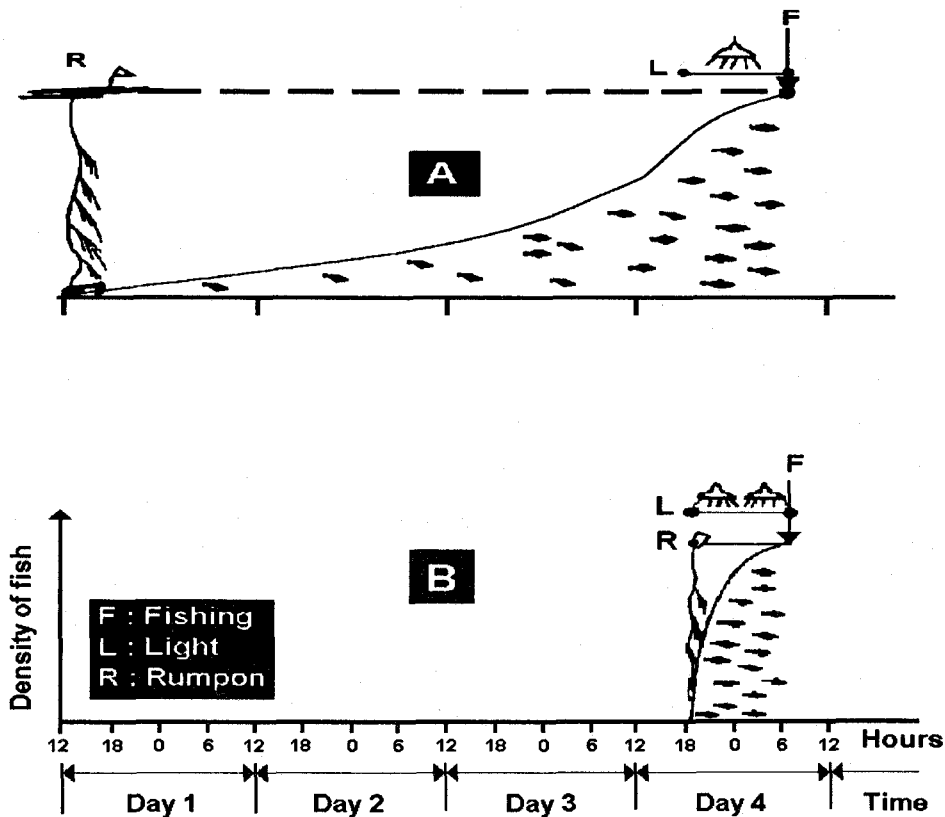


Figure 1 Phases of fish attraction. Old (A) and new (B) fishing tactics.
Gambar 1 Tahapan pengumpulan ikan. Taktik lama (A), baru (B).

²Indonesian name of the FAD.

The article examines the relationship which can exist between the fish and the fishing vessels and what hypotheses can be built to explain the use of such fishing devices in the Java Sea.

MATERIAL AND METHODS

Material

To study this relationship, 3 sets of information are available :

- Two which relate to the fish abundance and fish behaviour. They are the acoustic densities and the number of fish schools.
- The third one is the location of the fishing vessels on the fishing grounds.

In the framework of the Pelfish Project³, some acoustic cruises were performed in the Java Sea, the Makassar Strait and the South China Sea. Echo-integration was done every nautical mile (ESDU : Elementary Sampling Distance Unit) and was expressed in UI (Unit of Integration) (Petit *et al.*, 1995). The number of fish schools integrated along these cruises was counted, using the echograms.

During these cruises, the fishing grounds of the purse seiners were prospected. Along its course, the R/V Bawal Putih I passed through vessels' concentrations. The fishing vessels were then plotted on the radar of the ship. The range of the radar was 15 nautical miles (Nm), greater than the inter-radial distance (10 Nm). Then, all the fishing vessels were counted. When the distance between two echoes was less than the length of the seine net, one of the echo was discarded.

Two acoustic cruises with such plots were chosen for the study (Fig. 2) :

- The first one was performed in October 1992 in the Java Sea around Masalembo Island. The acoustic prospection lasted 4 days and 3 fishing vessels' clusters were identified.
- The second one took place in April 1993 in the South China Sea near the Natuna Islands. During the cruise, 1 fishing vessel's cluster was covered during one day at night and daytime. This last one was used as a witness for the vessel clusters individualized in the October 1992 cruise.

Due to the proximity of the equator, the length of the night and the daytime was chosen equivalent, the night starting at 5:00 p.m. and the day at 5:00 a.m.

Methods

Areas of the fishing boats

Areas where the purse seiners were observed have been defined and used to stratify the acoustic data. Purse seiners tend to be clustered in space. The limits of the clusters have been defined using the acoustic tracks and the most distant fishing vessels. Square limits have been set to the boat clusters. The minimum distance between boats has been adjusted to draw a boat cluster limit from the most outside boats. They make up patches of 20 to 30 nautical mile range (Fig. 3). Data have been then separated in two groups depending on whether they were standing inside or outside the boat areas. The effect of the boat clusters on the fish was tested using the ratio between night and day acoustic densities.

The probability of the boat areas in the surveyed field was estimated by the number of acoustic data standing within. Each data was randomly selected according to the boat group probability and the ratio between night and day densities was then computed for the selected data. This procedure was repeated 200 times and the probability distribution frequencies (pdf) of the ratio were generated. The experimental ratio was then compared to the ratio value corresponding to the 95% quantile.

³Pelfish. The Java Sea Pelagic Fishery Assessment Project is funded by the European Union and aims to assess and manage the purse seine fleets of the Java Sea.

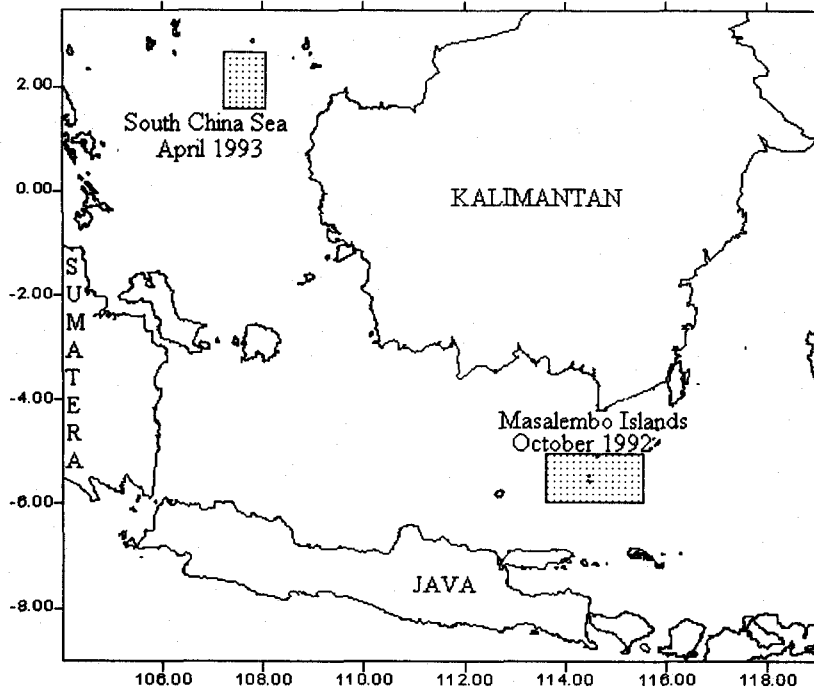


Figure 2 Location of the 2 acoustic cruises used for the study.
Gambar 2 Lokasi 2 pelayaran akustik yang digunakan pada studi.

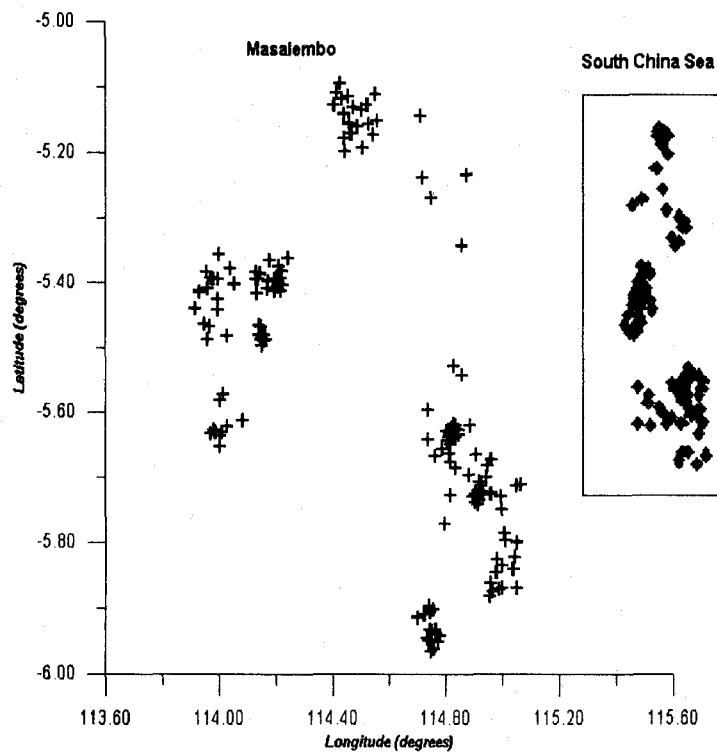


Figure 3 Locations of the purse seiners on the Masalembu fishing ground in October 1992 and the South China Sea fishing ground (April 1993).
Gambar 3 Lokasi kapal-kapal purse seine di daerah penangkapan Masalembu pada Oktober 1992 dan di Laut Cina Selatan (April 1993).

Variograms

Variograms were used to analyze the spatial correlation in the spatial distribution of acoustic fish densities and fishing vessels. The variogram enables characterization of the spatial correlation in a process taking values at every point in space. Its use was first introduced by Matheron (1971) to characterize spatial correlation of a natural process. It quantifies the discrepancy between values as a function of the distance separating them. It is better interpretable when the data are a homogenous set and show no trend. In general, the variogram increases with distance and reaches a sill for a given distance, thus called the range. An increase in the variogram with distance shows spatial correlation between point values, as points farther apart will be more different from the closer ones. When the variogram stays flat, there is no spatial correlation, as close points are as different as distant ones. The range measures the average dimension of the influence area around a point. The nugget effect is a sharp increase of the variogram for the smallest distance ($\gamma(0)=0$, $\gamma(h)=c$ as soon as $h>0$) and quantifies a discontinuity in the spatial distribution as it measures an irreducible discrepancy between very close points. Variograms were computed using the software EVA (Petitgas and Prampart, 1995) on the density values by day, by night inside and outside the vessel areas and also on the presence indicator of boats. To generate this last variable, the surveyed field was discretized with a square grid of 1 Nm mesh. The presence of, at least one boat per cell, was coded by one and the absence by zero.

Cross-tables

The relation between the number of schools and the fish density was analyzed by means of a cross table in 4 different situations : inside and outside the vessel clusters, during day and night time. Classes for the acoustic density and school number were defined and a table was generated in which the rows correspond to the density classes and the columns to the school classes. The probability for each table cell was estimated as well as the cell contribution (in percentage) to the biomass. This was performed for each of the four situations.

Distance between boats

In each cluster, all the distances between boats were computed and the frequency distribution of the distances was estimated.

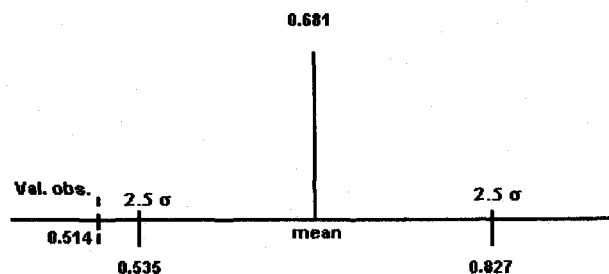
RESULTS

The boat areas were found to have a significant effect on the day-night ratio of the fish density (tab. 1). The ratio observed in the vessel cluster was equal to 0.514 and found external to the 95% confidence limits of the normal law.

Table 1 Results of the test performed on the day/night ratio.

Tabel 1 Hasil uji pada rasio siang/malam.

Haulings	1	3	18	52	55	33	27	7	4
Ratio d/n	.5	.55	.6	.65	.7	.75	.8	.85	.9



The distribution of the acoustic densities and fish schools are given in Figures 4 and 5. The variograms performed on the acoustic densities and fish schools show little differences among the two fishing grounds (Fig. 6, 7, 8).

The acoustic densities have a good structuring in and out of the vessel clusters. That structuring increases between day and night in the vessels cluster. From day to night, the range increases from 4 Nm to 8 Nm. The variability which is not explained by the variance (nugget effect) stays stable between day and night in and out of the vessels' clusters. The sill (total variance) increases from day to night.

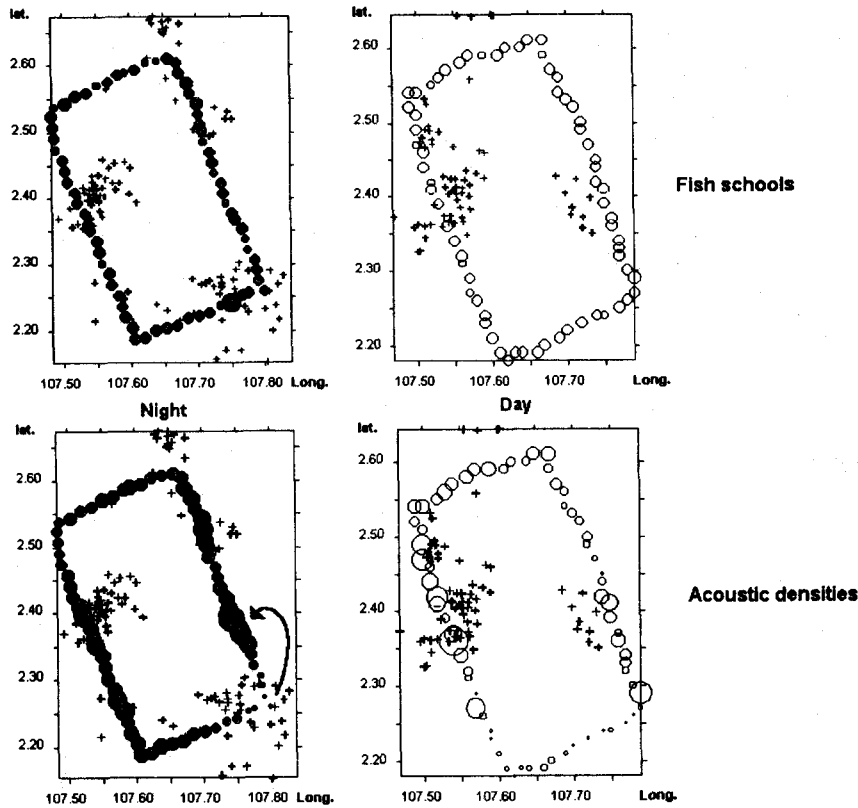


Figure 4 Acoustic densities and fish schools distribution during the South China Sea cruise in April 1993.

Gambar 4 Kepadatan ikan dan sebaran kelompok ikan pada pelayaran di Laut Cina Selatan pada bulan April 1993.

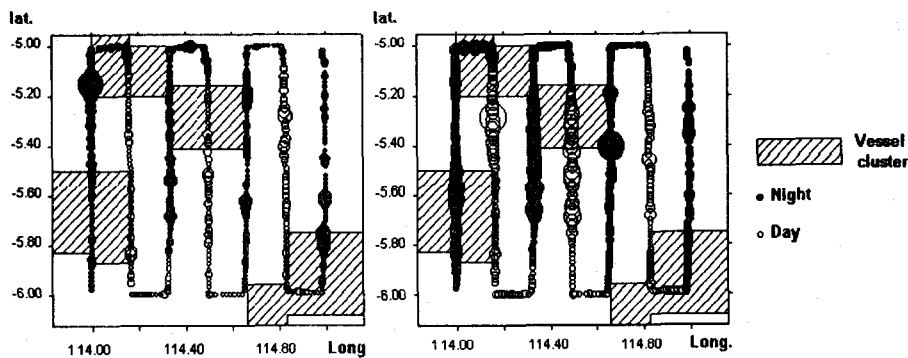


Figure 5 Acoustic densities and fish schools distribution during the Masalembo cruise in October 1992.

Gambar 5 Kepadatan ikan dan sebaran kelompok ikan pada pelayaran di Masalembo pada bulan Oktober 1992.

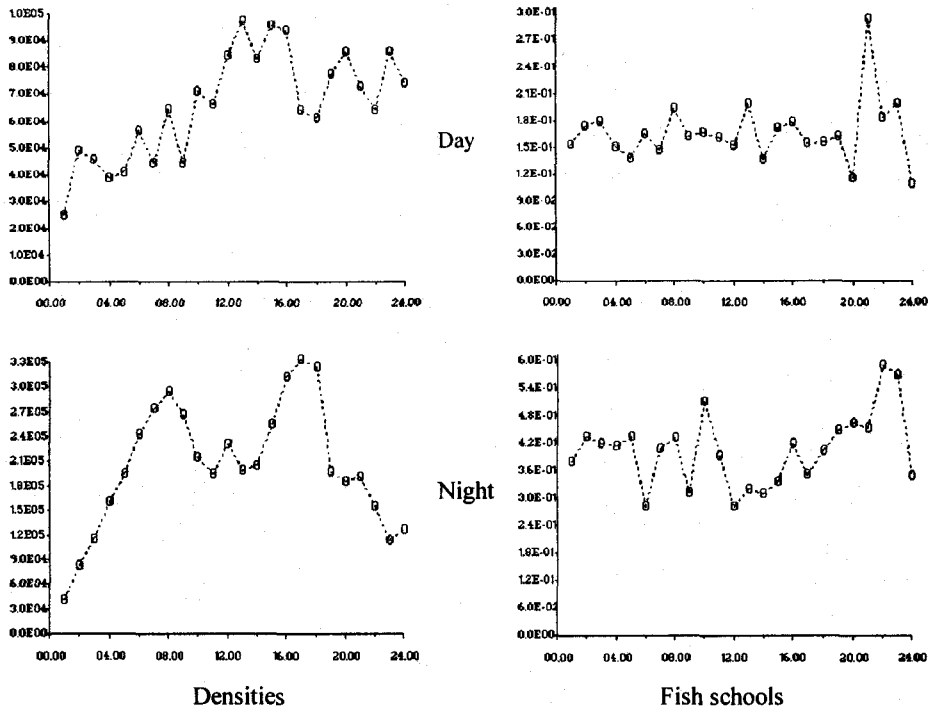


Figure 6 Variograms on densities and fish schools during the South China Sea cruise (April 1993).

Gambar 6 Variogram kepadatan ikan dan kelompok ikan pada pelayaran di Laut Cina Selatan pada bulan April 1993.

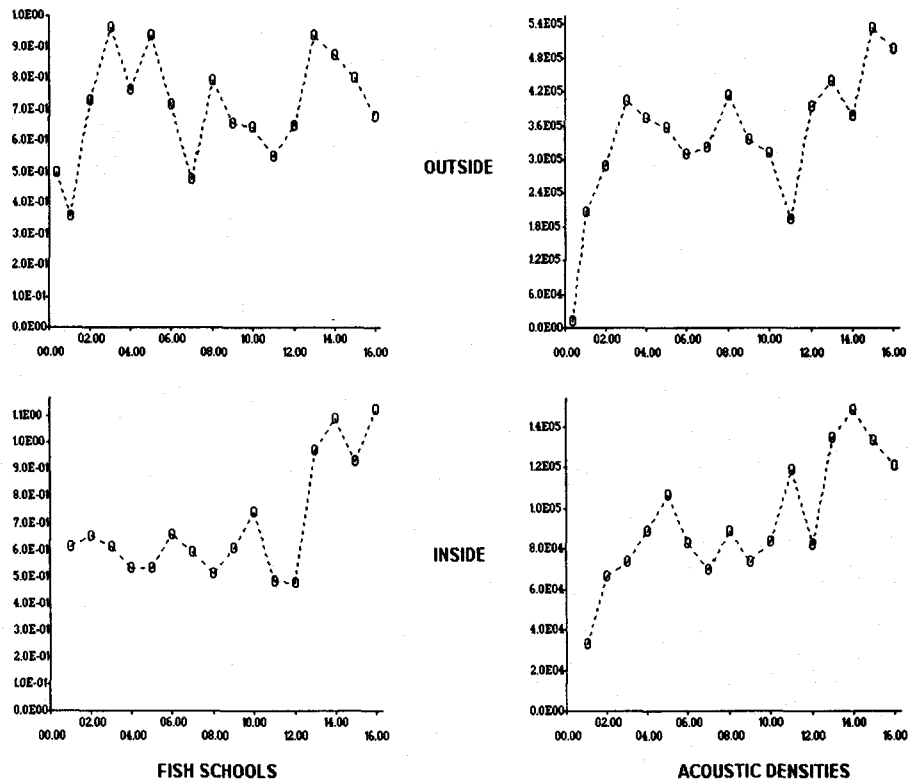


Figure 7 Acoustic densities and fish schools variograms at daytime during the Masalembu cruise in October 1992.

Gambar 7 Variogram kepadatan ikan dan kelompok ikan pada siang hari pada pelayaran di Masalembu pada bulan Oktober 1992.

The variograms of the fish schools show no structuring at daytime but, at night, structuring appear in and out the vessels' clusters. In the China Sea the low number of fish schools does not allow to see if any structuring occurs. At night, the range varies from 12 Nm in the clusters, to 4 Nm out of them. The nugget effect is low and the sill follows the same trend as for the acoustic densities.

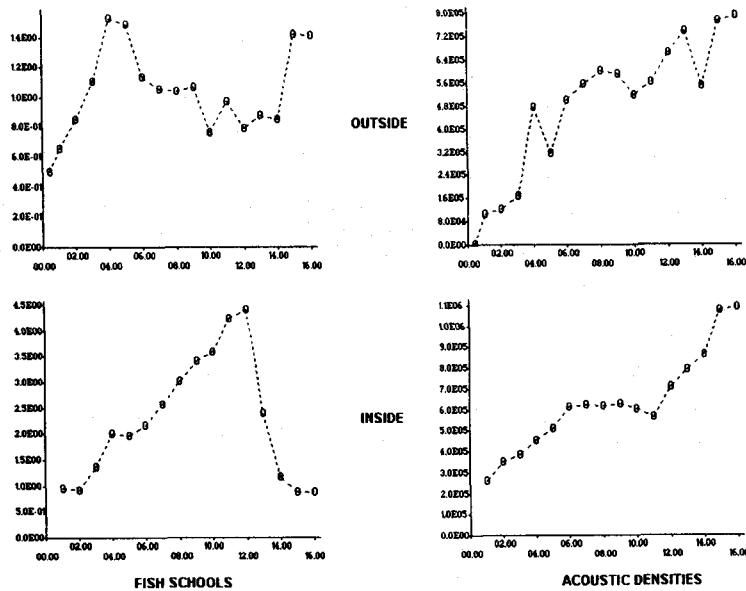


Figure 8 Acoustic densities and fish schools variograms at night during the Masalembu cruise in October 1992.
Gambar 8 Variogram kepadatan ikan dan kelompok ikan pada malam hari pada pelayaran di Masalembu pada bulan Oktober 1992.

The variograms calculated on the vessels' presence show that a structure exists between 5 to 10 Nm (fig. 9).

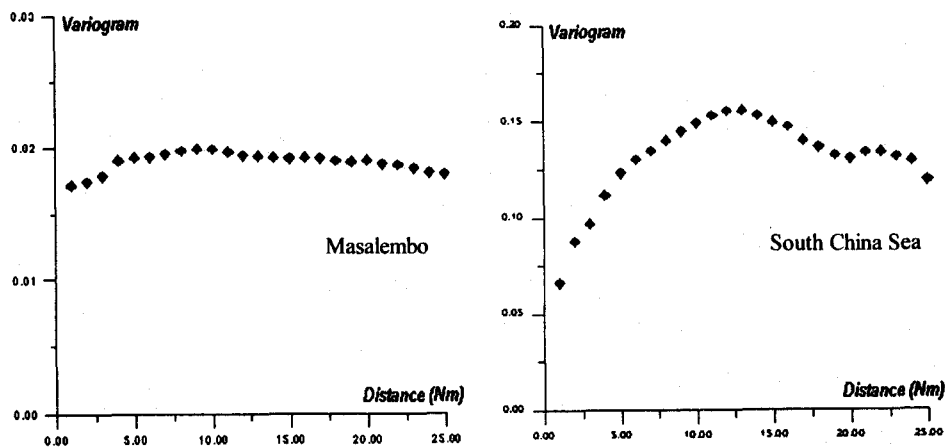


Figure 9 Variograms of the presence of boats during the Masalembu and South China cruises.
Gambar 9 Variogram keberadaan kapal ikan pada pelayaran di Masalembu dan Laut Cina Selatan.

The fishing vessels are located in clusters. The high nugget characterizes the fact that a boat cluster contains many empty areas. No large structure is visible, meaning that the vessel clusters are not correlated.

The night-daytime comparison of the cross tables (acoustic densities/number of fishing schools) (Fig. 10, 11, 12) presents the same evolution on the 2 fishing grounds. Between daytime and night the probability to have fish schools in each class of density increases a lot and the distribution of the biomass by class of fish school expands towards higher classes. This trend is much stronger within the vessel clusters than out.

The increase in the mean density between night and daytime is 2 times higher within the vessels' clusters than outside. The number of fish schools is multiplied by 2 (South China Sea) or 3 (Masalembo) from daytime to night in the vessels' clusters. This increase is 4 times higher than out of the vessels' clusters.

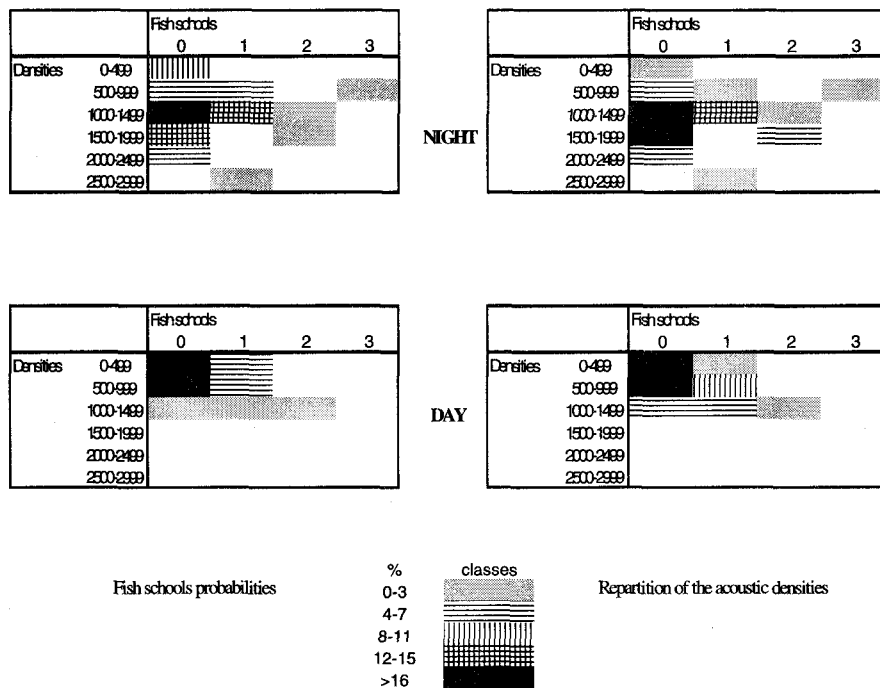


Figure 10 Results of the cross tables within the vessel cluster prospected in the South China Sea in April 1993.

Gambar 10 Hasil tabel-tabel bersilang di dalam cluster kapal-kapal purse seine di laut Cina Selatan pada April 1993.

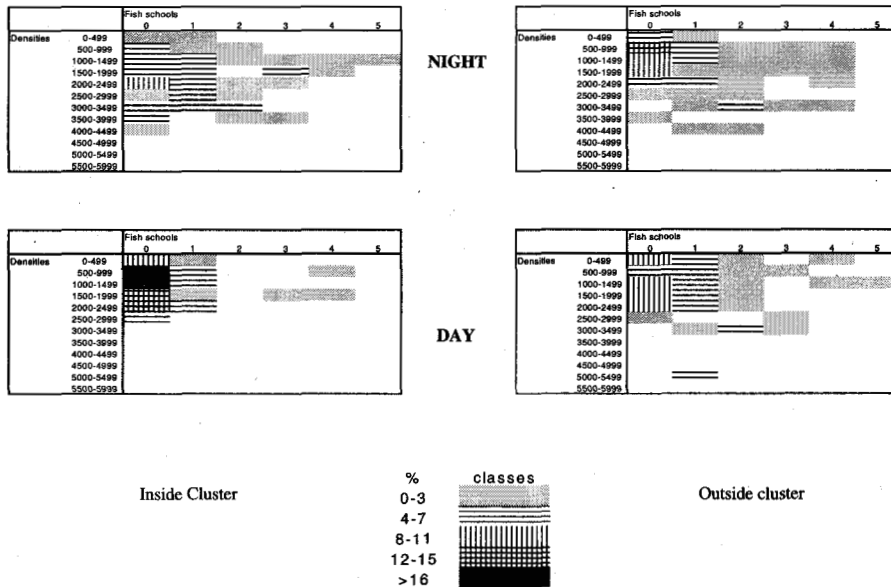


Figure 11 Distribution of the acoustic densities (percent) expressed in UI according to the number of fish schools during the Masalembu cruise in October 1992.
Gambar 11 Sebaran kepadatan relatif (persen) menurut jumlah kelompok ikan pada pelayaran di Masalembu pada Oktober 1992.

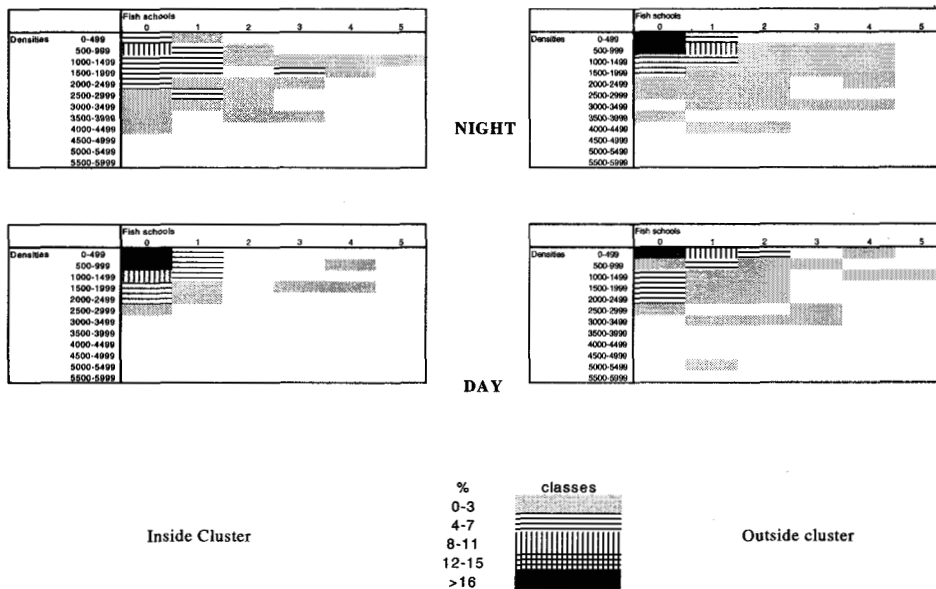


Figure 12 Distribution of the fish school probabilities according to the acoustic density classes during the Masalembu cruise in 1992.
Gambar 12 Sebaran peluang kelompok ikan menurut klasifikasi densitas pada pelayaran di Masalembu pada Oktober 1992.

Table 2 Summary of the results found during the Masalembo and South China Sea cruises.

Tabel 2 Ringkasan hasil analisis pelayaran Masalembo dan Laut Cina Selatan.

Masalembo			Inside Cluster			Outside cluster		
Acoustic		Variogram	density	schools	schools cl.	density	schools	schools cl.
	Night	sill	6,0 E05		1,5 E-01	5,6 E05	1,0 E00	2,4 E00
		nugget	2,0 E05	1,0 E00	3,0 E-02	0	4,0 E-01	1,0 E-01
		range	7	12	2<x<3	8	4	2<x<3
		structure	+++	++	+	++	++	++
		mean (UI)	1760			1146		
	Day	sill	8,0 E04	6,0 E-01	1,6 E-01	3,6 E-05	7,0 E-01	2,0 E-01
		nugget	2,0 E04	6,0 E-01	1,6 E-01	0	5,0 E-01	0
		range	4			3<x<4		3
		structure	++	0	0	++	0	++
		mean (UI)	890			952		
Number schools	Night				113			130
	Day				23			84
Nautical miles	Night				96			163
	Day				68			120
Nb. schools/mile	Night				1,18			0,80
	Day				0,34			0,70

China Sea			Night			Day		
Acoustic		Variogram	density	schools	schools cl.	density	schools	schools cl.
	Inside cluster	sill	2,0 E05	4,0 E-01	2,0 E-01	4,75 E04	1,5 E-01	1,3 E-01
		nugget	1,0 E04	3,0 E-01	1,2 E-01	1,0 E04	1,3 E-01	1,0 E-01
		range	6<x<8			4,12		
		structure	++	0	0	++	0	0
		mean (UI)	1260			530		
Number schools					22			11
Nautical miles					69			68
Nb. schools/mile					0,32			0,16

++ Good structuring + Structuring 0 No structuring

DISCUSSION

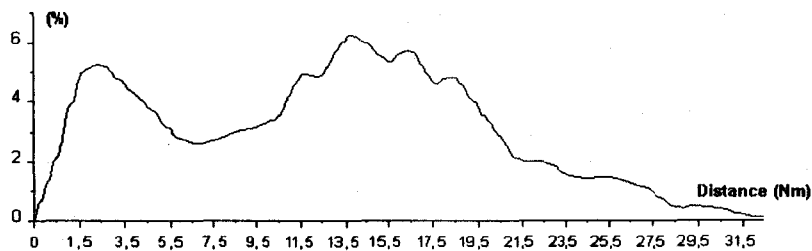
From the study of the 2 cruises the acoustic densities and the number of fish schools increase from daytime to night and that increase is far higher in the vessels' clusters than out of these clusters.

It seems that at night, a fish population, which is not integrated during the daytime, appears. As this phenomenon is observed in and out of the vessel clusters, only fish living close to the bottom at daytime and rising at night, can explain such result. That fish tend to form schools.

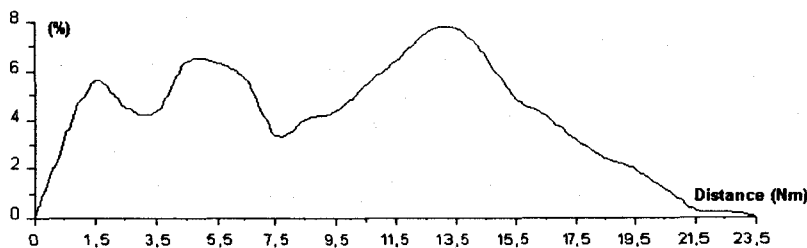
The fishing vessels are able to detect the concentration of fish near the bottom and the fishing tactics used by the fishing vessels amplify a natural phenomenon. Most of the marine animals show a positive phototaxism and tend to rise at night. The use of the light increases a lot that trend. That hypothesis matches well as long as the light plays the main role in the aggregation. That is the case in the seine net fishery now, but ten years ago that was the raft which was the initiator of the aggregation. Did fishing vessels substitute their targets ? Or did any modification in the environment of the Java Sea induce different fish behaviour ?

The study of the catch composition of the seine nets showed no drastic changes. The technical innovations appeared in 1986-1987, when catches decreased a lot. It was an adaptive answer to unfavourable environment. But as this environment recovered, the changes in the fishing tactics were proved a lot efficient. Then, bad catches induced technical changes which were better adapted to the fishing conditions than the old ones.

The study of the structure of the fishing vessels using the frequency curve of their distance (Fig. 13), and the fishing logs of some seiners can show us if the fishing vessels are able to alter the fish concentrations.



South China Sea. 106 Vessels



Masalemba (cluster I). 37 vessels

Figure 13 Structure of the vessel clusters found during the Masalemba and South China Sea cruises.

Gambar 13 Struktur *cluster* kapal penangkap yang ditemukan pada pelayaran di Masalemba dan Laut Cina Selatan.

A vessel cluster is structured in 2 zones (Fig. 14) :

- The first one named “nuclear zone” is defined by a high concentration of fishing vessels close from each other. It is the area where the concentration of fish and the competition among the vessels is the highest.
- The second one named “residual zone” is characterized by a low number of fishing vessels and is a zone where the fish concentration decrease and where the competition among fishing vessels is low.

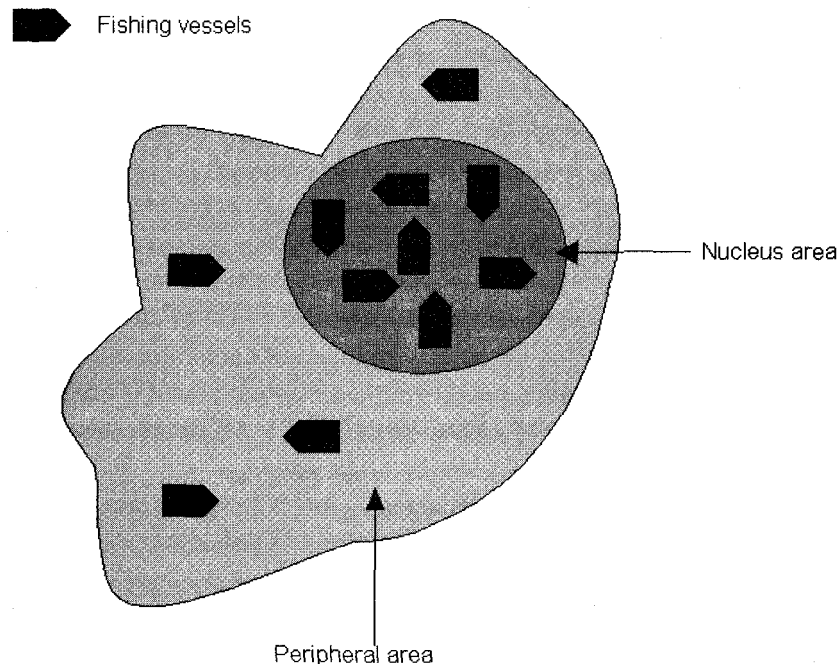


Figure 14 Structure of a vessel cluster in the Java Sea.
Gambar 14 Struktur *cluster* kapal penangkap di laut Jawa.

In such zones, the catch/set varies a lot among the fishing vessels. At night, the fish is aggregated under the fishing vessels, and peaks and holes of densities are created in the fish concentration. Such clusters can remain as long as the catch/set is attractive (Fig. 15).

With the help of the light and the FAD's the fishing vessels alter the fish concentration.

The knowledge of the relationship between fish and fishing vessels is highly interesting. It can give information on the fishing efficiency of the fishery. If the fishing vessels are able to locate the fish concentrations and to alter these last ones in order to get high catch/rate, their fishing efficiency is high. In the Java Sea, the purse seiners seem to have a really efficient fishing tactic that they improved by using electric lights and radios, which made them more mobile. Then their fishing efficiency has grown a lot since 1987.

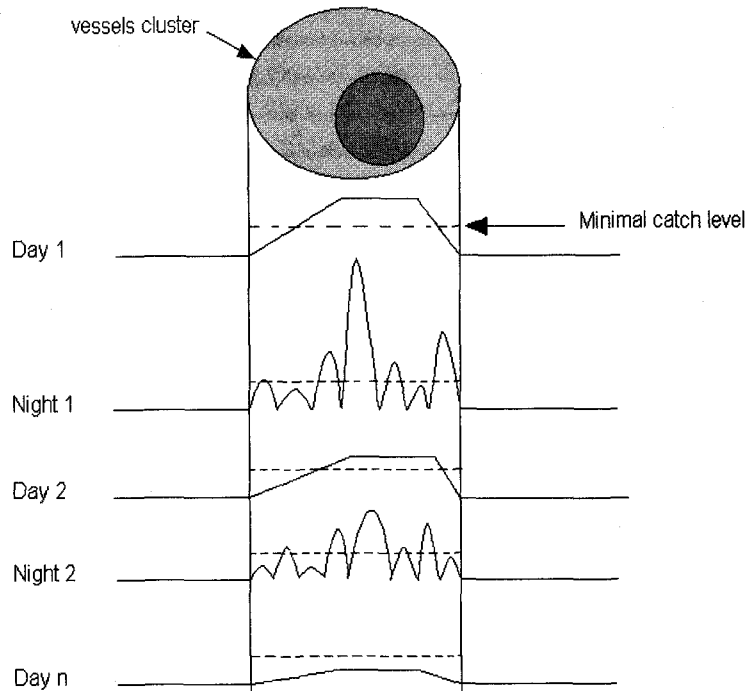


Figure 15 Scheme of the relationship between fishing vessels and the fish concentration in the small pelagic fishery of the Java Sea. Such concentration can last 4 to 6 days.

Gambar 15 Skema hubungan antara kapal penangkap dengan konsentrasi ikan pada perikanan pelagis kecil di Laut Jawa. Konsentrasi semacam itu dapat bertahan 4 sampai 6 hari.

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DISCUSSION

(Chairman Dr. MARCHAL)

Dr. GERLOTTO comments : "I am very happy to see that somebody is able to use acoustic data for fishery management; very often, people expect only biomass estimates for making fishery management meanwhile acoustic data may bring much more information."

Dr. MASSE

Q : - When you say that the density is strong, do you mean scattered fish and schools or only schools ?

A : - Only schools.

Q : - You say : the density is higher during the night and the number of school either. We can deduce that there are more small schools, which can represent a contrary.

A : - On the fishing zone, there are more small schools. The fish tend to aggregate in small schools near the fishing vessels. But density is much higher.

Q : - From your last table, was the light able to attract very big schools or more small schools ?

A : - During this acoustic cruise, we did not pass near the fishing vessels; so, we did not make this kind of study.

Dr. NURZALI

Q : - Is there any complain about the small or mini purse seiners in the Java Sea, from artisan fisheries which use fishing gears like ring net, rumpon, payaos ? Do their catches decrease ?

A : - Two years ago, fishermen from East Java complained about large purse seiners. They were arguing they could not catch layang. The catches of artisan fisheries do not decrease. Until 1994, the catch of artisan fisheries reached 180,000 tons and in 1995, the catch was higher. But, we must be careful : fishing efficiency is very high and until now, we only have information on the nominal effort. We have to standardize this effort to see if the CPUE is still increasing or has already decreased.

Dr. DURAND

Q : - About your results of 180,000 tons, are you dealing about the total catch of pelagic fish caught by the seiners in the Java Sea ?

A : - The total caught by large and medium seiners.

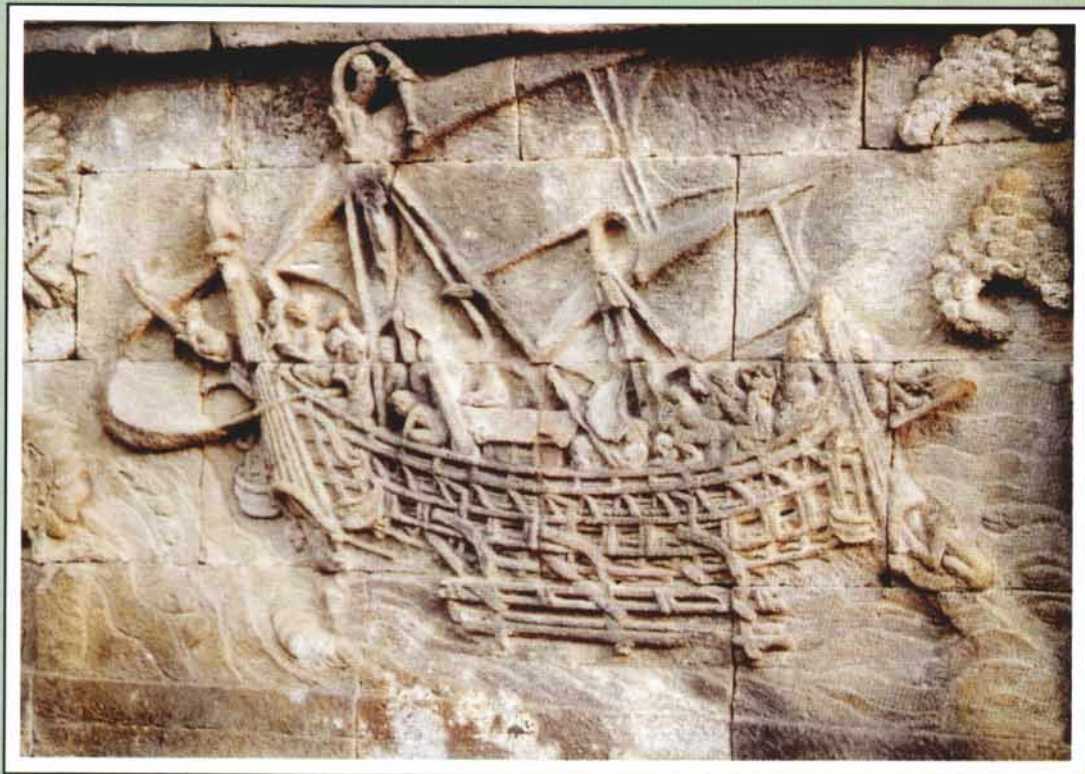
Q : - My question is about the last sentence you told us. Why do you think that we should try to have a better efficiency ? It could be linked with a general diminution of exploitation.

A : - Perhaps, we have to stop the increasing fishing efficiency. The vessels will become more and more efficient and will catch more. Meanwhile the stock remains the same, thus the pressure will increase a lot on this stock. As you know, we are dealing with small pelagic fish with highly valuable resources and we also have to be cautious about that.

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