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Bandungan 27th - 29th May, 1996

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

French Scientific Research
Institute for Development
through Cooperation

Akustikan 2
Proceedings
Bandungan, 27th-29th May 1996

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AKUSTIKAN 2

Proceedings of Acoustics
Seminar Akustikan 2

May 27th-29th 1996
Bandungan

PELFISH

Scientific Editors : D. Petit, P. Cotel, D. Nugroho
Java Sea Pelagic Fishery Assessment Project
Jl. Pasir Putih I, Ancol Timur
Jakarta 14430

1997

To our dear late colleague and friend Dr. Thierry Boely who, beyond the Task, has shown us Humanity, Dignity, and the Way to achieve this Project...

FOREWORD

Introducing this collection of acoustical works made up within the frame of the PELFISH Project, we discarded harping on the interest of such studies on marine environment in regard to wealth it yields; neither do we be put into figures the mere necessity for Indonesia to intensify oceanography research, given the rising part ocean is bound to take in her economic development : many books already have a great deal upon those topics.

Still, introducing these proceedings provides the opportunity to focus on interest that acoustical marine research can bring about. Acoustical research applied to fisheries was born about thirteen years ago, in the northern hemisphere, following fast technical improvements achieved during Word War II.

Used for poor-populated environment, ambition was to settle biomass assessment, thus to provide wealth indexes already oriented to allow a sustainable management for stocks.

It has been used in studying marine animal-life by a growing number of scientists.

Eversince, it has been facing detractors, probably since huge hopes have been sparked on, as aroused from over-simplifying generalisation. Using audio-waves properties in a liquid environment, interpreting measurement then analysing results can be flawed by bias and even blunt mistakes that has led to temporary disaffection.

Nevertheless waves propagating principle in a liquid environment is still the only way to get "remote sights" through the water worlds. Further fully-fledged acoustical steps were backed along by electronics and computer science. It is as well worth noticing that following these latter sciences, new ambitions arised, using these techniques aiming at analysing moves and behaviours, as there was no other observation tool but acoustics. Whereas there still remain bias, these brand-new investigation fields look promising, allowing to develop studies about fauna within the environment, as well as behaviour studies facing fishing devices.

Managing the sea is a quite ambitious task. For thousand years, sea grounds have been harvest areas; necessity is now to manage exploitation and to face this challenge.

If trying to carry on sustainable development, any way of getting knowing can turn out useful, as any management plan requires the most complete knowledge of the operated field.

First that means either physical or biological environment knowings.

The Java Sea, which the PELFISH Project deals about have been very little known for its physical functioning, as well as for its biological and environmental features.

Eventhough, as far as Humans do exert a pressure on it, any environment changes; those changings should be known as well to draw out a fully fledged management scheme.

First planned for the beginning of 1996, AKUSTIKAN 2 had to be postponed. Unfortunately enough, this delay had but negative incidence on attendance and participation : formerly appointed fellow members were not able to renew their commitment for May, especially South-Asian peoples; still, we enjoyed the opportunity to get an effective attendance from our French colleagues; their original communications show many of the application fields of acoustics. Reduced outsiders attendance results in a two-folds partition of the chapters : the first chapter gathers contributions coming from a broadly defined Javanese basin, the other one coming from outside this area. This seminar following a workshop, Akustikan I, that happened in 1994 on the same data base, it was considered a good thing to reprint results then gathered and exposed eversince at the IVth Asian Fisheries Forum in Beijing (16-20 October 1995).

Some contributions set out during AKUSTIKAN 2 will not be issued here, and we shall make apologies to the authors for it : Professor A.G. Ilahude speech about climatology and its consequences on Javanese oceanologic area, was highly interesting, but we could not get his paper in time. Besides, the communication of Dr Hendiarti, was enthralling, but only dealt about remote sensing, and the one of Dr. Sihotang, deserves further work before publishing.

Before any further acknowledgements, let us have a special thought for late Mr. T. Boely, PhD, without whom those acoustical studies could not have been worked out.

We would like to give special thanks to Bogor University for its fruitfull commitments to this seminar, thanks to Pr B. Pasaribu interest for acoustical works carried out within the Project.

We also have to express our gratefulness to the crew of R/V Bawal Putih 1, and to Captain Sumitro, who allowed to achieve the surveys even through the difficulties in ship maintenance.

Readers of these proceedings shall also praise our French colleagues for the interest of their contribution as well as for the support they provided for processing acoustical data of PELFISH.

Furthermore we are glad to thank here :

The European Union,
The Indonesian and French Governments, which funded up the Research Project,
The Project Staff, for its scientific and technical assistance, specially Dr J.M. Ecoutin and
Mr D. Maison , for the kindness they showed to correct and help for the editing of this book.
and all secretaries for their help, especially N. Agustinah for the presentation of this book.

CRIFI Editions kindly agreed to undertake printing and issuing for this book, we would like to express special thanks for them, and especially towards head office Mr. Fatuchri Sukadi, PhD.

Acoustics Seminar AKUSTIKAN 2

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VINCENT DE VISSCHER

DEVELOPMENT COUNSELLOR
EUROPEAN UNION REPRESENTATION IN INDONESIA

Pak Sukotjo, Director General of Department of Fisheries,
Pak Fuad Cholik from CRIFI,
Mr. Marliac from ORSTOM,
Pak Durand, Director of PELFISH, Pak Widodo as Directors of the Project,
Experts from ORSTOM,
Indonesian experts,
Ladies and gentlemen,

It's a real pleasure on behalf of the European Commission to be here with you today for the third time. I believe it's a "be back in the family." It's already the third time we meet together, one was for BIODYNEX, the second one was for SOSEKIMA, and now AKUSTIKAN 2. We should not forget AKUSTIKAN 1. But, I think it's very good that we meet together to share your results and I understand AKUSTIKAN 2 is really sharing experience of gather in Indonesia and also around the world. We see that as a real and in the field of transfer of technologies. My speech will be very short because I understand you have 28 communications all together and that's me say, it takes some time, but I just want to go back in History : in 1986, the European Commission decided to join forces with the French Government and particularly ORSTOM to finance this Project. Now, we are in 1996, about 10 years although this project didn't last 10 years absolutely, it was started with Pak Widodo and Pak Boely and continued by Pak Durand now we coming to an end for the European Commission and let me say that the Project used almost the last drop of financing, I was reminded by Pak Durand that he was still expecting 23,000 ECU. I am pretty certain that the money has been used till the last drop. Now, what we expect is that, now, we have to analyze the results which have been accumulated by this Project, not only technically but also on the management side and I understand we have still to see the report of the experts of the management side. My suggestion will be of course the European Union will be interested to continue to collaborate with the Directorate of Fisheries and also with other colleagues from AARD, CRIFI,etc. I think it's a wish to continue; now, we will have to discuss the framework; I think time has come to take stuck of the scientific results which have been gathered, you have indicated to us which way to take, how to manage the resources and that's what is so important. We have, as I said, to discuss the over framework allowing the European Commission to join force once again with the Government of Indonesia to embark on, why not, on another project. The Commission wants certainly to have a project which is based on partnership where the European and the Indonesian can share resources and where transfer of technology can take place. Considering the fruitful exchanges, I think we can manage to have this framework arranged. Now, in closing this Project in about one month time, it's for me also the time to leave Indonesia after four years, and going back to my headquarters in Brussels. I have been assigned to be in charge of, in a technical unit of all the Agriculture Projects in Asia.

So, I guess that it will be another position where I can watch Indonesia and, why not, also to push projects in this country. So, I wish you all the best for this seminar and hope that, with the scientists, you will gather forces together and also indicate to the Government the best way to manage its resources. Thank you so much.

MR. SUKOTJO HADISUKRISNO

DIRECTOR OF AQUATIC RESEARCH DEVELOPMENT ON BEHALF OF THE DIRECTOR GENERAL OF FISHERIES

Distinguished Representative of the European Commission,
Distinguished Director General of the AARD which is represented by the Director of CRIFI),
Distinguished Chief of Fisheries Service for Central Java,
Distinguished Director of ORSTOM,
Distinguished Directors of PELFISH,
Distinguished guests,
Ladies and gentlemen,

This is a proud privilege for me to be with you in this morning at this opening ceremony for the second cession of the aquatic seminar AKUSTIKAN. The seiner activity has developed rapidly in the last decade, however it is not spread evenly throughout the areas. The seiner activity is concentrated in several fishing grounds which are providing with areas of dense population such as Java Sea. The situation may undermine the sustainability of fishery resources in the areas. To overcome the problem, the Directorate General of Fisheries has taken measurement to encourage fishermen to increase their capability to breed to the other areas that are still underexploited. Recently, fishing activities in the Java Sea have extended to other areas beyond the Java Sea such as the Karimata Strait and the Natuna Sea. Fishery resources are renewable resources; however their capabilities are limited. There are needs of an adequate fishery resource management in order to keep the resource sustainability. The fishery management concept quite depends on data base of, for example, fishery resources of pelagic fish which will be discussed in this meeting. It is obvious that we hope the results of this meeting will be useful and applicable as a basic consecration in taking management policy in the Java Sea. As we all know, Indonesia is an archipelagic state which is mostly consisted of seas. Based on the signature to keep the Wawasan Nusantara principle that the unity of Indonesia accordingly seas around the islands do not divide these states separately one to the other, that is however a steady Unity. The Province areas do not have their own suffering right at the sea but central belong to the Central Government; it is shared into limited jurisdiction, for example, on fishery management, authority for fisheries using vessels less than 30 GT or 90 horse power. The main principle in giving limitation province jurisdiction by using a certain size for fishing vessel is aimed to reduce the conflict among the summon in the potential the fishing grounds where there are to be common fishing grounds for the fishermen. The mesh size and the power of fishing vessels assume the impact of limited scope of their fishing grounds when they are not far from their own base. However, in reality, overlapping fishing grounds cannot be at none. Taking into account the recent situation, the Director General of Fisheries has established a coordination Forum for Fishery Resource Management. This Forum is consisted of several Province Fishery Services with service men operating in the same fishing ground covered by the Forum. By this effort, it is so that such measurement related to fishing management can be taken and implemented properly. However, an adequate scientific data supporting is very important for the success of the mission; therefore, I call upon that the seminar can fulfill the requirement : suggest stock assessment data, migration pattern and etc. I am confident that the deliberation of the seminar will lead to meaningful recommendations we will surely happy in return. I wish to this seminar a success on behalf of the Director General of Fisheries, I declare the seminar AKUSTIKAN officially open. Let God bless all of you to do the best of what you think of our objectives.

DR. FUAD CHOLIK

DIRECTOR OF CENTRAL RESEARCH INSTITUTE FOR FISHERIES

Yang terhormat Bapak Direktur Jendral Perikanan yang dalam hari ini diwakili oleh Bapak Direktur Bina Sumber Hayati,
Distinguished Mr. De Visscher (Development Counsellor of the European Union),
Distinguished Mr. Marliac (ORSTOM Representative in Indonesia),
Distinguished Dr. Durand (PELFISH Project Director),
Distinguished guests, Ladies and gentlemen,

So for, I would like to convey my gratitude to the Director General of Fisheries, for opening this AKUSTIKAN 2; then, to all of the participants I would like also to express our gratitude for attending this opening ceremony and particularly participating in this AKUSTIKAN 2 seminar. Through this seminar I hope very valuable conclusion to set up alternative of management schemes of the pelagic fishery resources the Java Sea can generate. Ladies and gentlemen, fishery experts around the world are worried about too many fishers for the available marine fish stocks. They believe that the rate of exploitation of marine fish stocks has overpassed the maximum sustainability. According to Peter Reeble in "*The State of the World,*" *the catch has* fallen in all but two of the world's fifteen major marine fishing regions; in most of them it has shrunk by more than 30 per cent. Total world's fish production peak at around hundred million tons in 1989, and after a short decline rose to 101.3 million tons in 1993. According to FAO, about seven percent of the world's marine fish stocks are fully too heavily exploited, overexploited, depleted and slowly recovering. Only thirty percent of the world's fish stocks are considered underexploited or moderately fished and most of these stocks consist of *low market values*' species which indicate that improvement of the economic performance of all fisheries cannot be achieved without serious changes. The situation is further aggravated by an ever-growing human population indicating future growth in the demand for fish and fishery products and greater pressure for an increased supply.

Like here, in Indonesia, Marine Fishery is still a promise. Official report reflected that Indonesia Fishery has grown rapidly within the last decade, as indicated by each growth rate at 5.9 per cent per year. In 1993, the total fishery production amounted around 3.8 million tons which makes Indonesia one of the top ten of the global fish producing countries. Its exports have also increased significantly during the last decades, namely from 76,000 tons valued at 248 million US dollars in 1984, to 530,000 tons valued at 1 milliard US dollars in 1993. To the total fishery production, the marine captures contribute significantly accounted for 60 to 70 per cent per year and most of them are small pelagic species. Talking about small pelagic fisheries, and particularly of Java Sea, is very important for Indonesia, since the fishery provides their relative lead cheap protein resource to most Indonesian people and especially to people who live in the coastal areas, the fisheries also provide them with employment opportunities, post fishing and other insular jobs such as loading and unloading works, fish handler processors, etc. Since the trawler ban was effective in 1980, the pelagic fishery has become the only important fishery activity in the Java Sea. At first, the exploitation of fishery was carried out in a traditional manner by fishing artisans whose fishing operations were limited to coastal areas. After the trawler ban the pelagic fishery has been rapidly developing, especially the development of the purse seiner fishery.

The purse seine was introduced to Indonesia in 1968, however as a commercial fishing, the fishery only was started in 1971; it grew especially faster after the trawler ban was effective, when many trawlers were transformed into purse seiners. The size of the purse seiners has also been developed from mini or small purse seiner after the medium and the larger ones. Technological innovations of the purse seine can also be observed; recently, the use of *rumpon* has been gradually replaced by electrical lightening later it has become popular due to its effectiveness in concentrating fish.

The rapid development of purse seine fishery in the Java Sea is indicated by the number and size of the fishing vessels used and the increase of the pelagic fish production. The number of purse seiners has been doubled since the last fifteen years; in 1975 they were around 240 purse seiners, mostly the larger ones, operating in the Java Sea, the number has increased to 573 units in 1994; the fishing grounds have also become further from their bases especially Makassar strait and the South China Sea. Small pelagic fish landed in the North coast of Java has increased, in four ports in 1994 if compared to 1979 production; consequently fishing effort has been increased continuously since 1979; in consequence, the number of fishing days also increase from 6 days per trip to 25 days per trip in 1994. However, catch per unit effort decreases gradually since 1992.

What lessons can be learnt from the previous description of the global fishery situation and our pelagic fisheries ?

First, we must manage our fishery resources properly before it is too late. To be able to set up a proper management plan we need sufficient and accurate data and information on various aspects covering the stocks : environment, biology, fishery as well as socioeconomics with certain degree of accuracy. PELFISH Project has collected and analyzed data regarding the pelagic fisheries of the Java Sea, since the last five years and reported the finding to various channels among others through in-country seminars, such as AKUSTIKAN 1, BIODYNEX and SOSEKIMA, and now AKUSTIKAN 2, as other else through international forum.

Second, concerning the utilization of our fishery resources, we must apply the precautionary principle and responsible fishing category. This may be possible if our Monitoring, Controlling and Survey run programs would have been properly carried out. The question is how to apply the "MCS" program effectively.

Third, we have to reduce loss at every subsisting fishery business, starting from handling and transport of the catch, processing and marketing of products. At the level of fishing operation, it is important to reduce its cost and excessive mortalities should be well understood and observed by all the parties concerned. Fish quality deterioration among others due to excessive catch, longer duration of fishing trips, poor handling and transport is not only great loss but also wastage of the limited resources. Meanwhile, the consumer's concern on seafood quality and safety is growing significantly.

The three previous dimension factors namely the proper management of the fishery resources requires precautionary and responsible fishing approaches in the utilization of the resources and reduce losses at every level of fishery business system are basics to sustainable fishery development and to obtain optimal benefits of the utilization of the resources. These factors in term should be based on the best scientific evidence; the role of PELFISH Project, in this case, is very relevant and significant.

Ladies and gentlemen, before I conclude my speech, allow me to brief you about the Project, just to refresh our minds about it. The PELFISH Project aims at a better knowledge of the small pelagic fish stocks in the Java Sea and yielded exploitation with the ultimate, allowance to build a proper management scheme of the resources. To reach this goal we need to have many more data on environment, liable statistical data, knowledge on the biology of the main species, as well as on socioeconomic. Some of the data have been collected, analyzed and reported through many means among others through workshops and seminars such as this AKUSTIKAN 2. Several findings of the Project and of other relevant researches will be presented and discussed during this seminar. It is interesting to note that dealing with the fish quality, a number of studies have been performed: a new design of fish hold insulation on board the vessels improves significantly the quality of fish, while the use of crushed ice in handling on board will reduce the damage of the fish; a number of biological population dynamics studies come up to several researches which are important for developing management strategy of the fisheries. Socially and economically speaking, the pelagic fishery of the Java Sea plays a significant role to provide with food, job opportunities and income. All these results will be very useful in generating systemic approach of fishery management for sustainable development.

Not all the data and information as I told you which have been collected, so far have been analyzed. Some more data are needed to be collected, for example, data on mini purse seiners; consequently, it seems to me that it is necessary to have enough scientists having capability to analyze those data, especially on acoustics and biology as well as other, and to collect the data on mini purse seiner fisheries. So, further training and collaboration with the European Union and ORSTOM will be very helpful to perform that purpose. In doing so, we will have sufficient input for setting up fishery management alternative based on various approaches. This alternative of management scheme will be conveyed to DGF as the Agency responsible for the fishery development in Indonesia and hopefully will be further transferred to various DINAS Perikanan at the provincial level. I hope the output of this seminar will be fruitful for our management scheme of Java pelagic fishery in particular. Wishing you a very fruitful discussion and success. Thank you very much for your attention.

Dr. Alain Marliac

ORSTOM REPRESENTATIVE FOR INDONESIA

Mr. Sukotjo, Director General of Department of Fisheries,
Mr. Vincent de Visscher, First Secretary at the Commission of the European Communities Representation in Indonesia,
Mr. Fuad Cholik, Director of CRIFI,
Mr. Jean-René Durand and Mr. Johannes Widodo, Directors of the PELFISH Project,
Ladies and gentlemen,
Dear colleagues,

ORSTOM is a Scientific Research Institute for Development through Cooperation- as it may not be conspicuous from its acronym (the old one which our African partners asked our Director General to keep in 1982).

The Institute under the authority of Ministry of Scientific Research and Ministry of Cooperation, has been given a certain number of tasks among the French national scientific research institutes network.

The general objective of ORSTOM being to run research for development and research upon development, these tasks can be summarized as follows :

- to give scientific responses to partners' questioning in developing countries,
- to support the development of research in developing countries (especially through partnership and training,
- to study the Development in itself, that is to take it as a scientific object.

From the general point of view, ORSTOM has a good expertise concerning the analysis of tropical environments, their resources and the societies which live upon them. On the grounds of fifty years experience around the world, it has built its own problematic obtained from an internal, theoretical and methodological debate run from the level of General Direction and Scientific Board down to Scientific Commissions and Research Units in the field. In the field means really to be on the spot during research as well as in the international institutions, seminars, publications, and so on. Of course, this ORSTOM problematic takes into account today global development theories particularly on environment and sustainability. Thus, ORSTOM appears well equipped to take part in Environment resources and Society studies within the scope of sustainability which has become one of the main world-wide Research objectives now.

Evidently, considering its own dimensions : personnel, status and budget, ORSTOM cannot do anything, anywhere, even if it may mobilize the other French Research Institutions, as well as European ones when necessary and even if it may build associations with other national bodies or international scientific Research Institutions.

These first considerations being taken into account a limited number of five main themes has been defined by the Institute for the next years among which one is covering your seminar; it is :

EXPLOITATION OF NATIONAL RESOURCES AND SUSTAINABLE DEVELOPMENT

In developing countries, natural sustainable resources are an important share of food input of a great part of the Population. Marine and Inland Fisheries, agriculture stock-farming and forest exploitation's are still the basis of family economies in rural areas. Moreover, they represent, for some developing countries, a big part of their exportations.

It has been thought, for years, that Development was to be run in terms of new environments or new species which were underexploited since then to be opened. This is now rejected as Environment's degradation is accelerating as resources are diminishing thanks to short- term productivity. The concept of long-term management of resources as a warrant to their reproduction has now been fully accepted.

Within this field, our Institute has already developed varied Research programs among which I would underline one :

DYNAMICS AND USE OF LIVING MARINE RESOURCES IN THEIR ENVIRONMENTS

This theme encompasses methods and techniques used to study the different resources at issue : their nature, characteristics, distribution and behaviour of the species.

Today, the pelagic fishes of Java Sea are concerned and this seminar, organized by the PELFISH team, aims at offering the first results obtained with the help of acoustic technologies through four years' evaluation campaigns made by ORSTOM and BPPL researchers in the Java Sea.

We are very satisfied to see that this long and friendly partnership between ORSTOM and AARD/BPPL whose results will be displayed in part this week, took this opportunity to show experiences and researches made in other continents within the field of marine acoustics. This is an example of South-South cooperation which ORSTOM promotes.

As PELFISH is coming to an administrative end, we take the opportunity of this meeting which will be another landmark of its activities such as BIODYNEX, SOSEKIMA and AKUSTIKAN 1, to underline that PELFISH as a general scientific program is not over. A threefold development period which witnesses for its achievements is prepared by its team of researchers. It is :

- finalization, dissemination and valorization of PELFISH results,
- building of an Indonesian-scale project, based on PELFISH experience in the Java Sea,
- technological innovations such as fish quality and management.

Let us conclude by the wish that ORSTOM, AARD and hopefully the European Commission will succeed in administrative building and launching of these new projects.

Thank you.

PRESENTATION OF THE PELFISH PROJECT AND THE SEMINAR AKUSTIKAN 2

JR. DURAND

LADIES AND GENTLEMEN

On behalf of PELFISH Project and with the approval -- I hope -- of my friend Dr. WIDODO, co-director, I will introduce quickly PELFISH and this Seminar.

First, I will recall the main objectives and contents of this multidisciplinary research and development program.

The PELFISH project which studies the fishing activity in the Java Sea is sponsored by Indonesia (Agency for Agricultural Research and Development, AARD), France (French Research Institute for Development through Cooperation, ORSTOM) and the European Union (Directorate General I). Its activities are focused on offshore pelagic fisheries (mainly medium and large seiners' fisheries) and its main objectives are :

- the provision of scientific advice for the future management of this fishery;
- the improvement of the performance of this fishing system in terms of catch, conservation and distribution;
- the evaluation of the socio-economic impact of potential management measures and technical improvement;
- the enhancement of fisherman's income.

To reach these objectives, PELFISH has developed three main fields of activities :

- RESOURCES AND EXPLOITATION
It refers to fisheries functioning as well as to bioecology or fish population dynamics. A special attention is paid to fish behaviour and biomass estimation through echo-prospecting and integration.

- SOCIO-ECONOMIC STUDIES
They evaluate production costs, fish prices, incomes in the fishing sector and downstream. The research also targets the fisherman conditions of work, the role of women in the production and the respective weight of the formal and informal sectors.

- TECHNOLOGICAL INNOVATIONS
It is related to nets' design and its evolution, the implementation of electronic devices on the fishing boats, the evaluation of the fish quality and the methods of conservation.

We decided that the best way to disseminate and valorize would be to hold seminars in the main fields and publish the corresponding proceedings, so we had :

- BIODYNEX (**Bio**logy, Population **Dyn**amics and **Ex**ploitation) which took place in March 1994. The corresponding proceedings have been edited in June 1995 under the responsibility of M. Potier and S. Nurhakim .

- SOSEKIMA (***Sosio Ekonomics***, Innovation and **Ma**nagement) December 1995, in this same Bandungan place where we come back today. The proceedings will be edited under the responsibility of J. Roch.

And last but not least, this Seminar, for which we all gather during these three days. The acronym, AKUSTIKAN 2 has been built on two very obvious Indonesian words : ***Akustiks*** and ***Ikan*** (fish). The number 2 refers to a previous AKUSTIKAN 1 workshop held in Ancol in December 1994; the corresponding report has been distributed to all present participants.

The utilization of acoustic tools in Java Sea must be related to its special context. In most cases, echo-integration has been used to have first -- and very approximative -- estimations of global pelagic biomasses. It was performed generally on very large scales and these approximate estimations were nevertheless very useful as they apply to newly exploited resources. This is obviously not the case in Java Sea open waters as all fishing grounds have been prospected now. The possible "average optimal production" -- in other words sustainable -- should be more easily and better estimated through bioecological results and exploitation data, rather than by means of biomass evaluation. Our interest for acoustics studies was focused on other topics like small scale variabilities, fish behaviour, fisherman tactics... in the frame of this multidisciplinary study.

From these last points of view, the preliminary results (Petit *et al.*, 1995; Luong and Petit, 1995; Nugroho *et al.*, 1995) give valuable information on the functioning of the system.

- They confirm the overdispersion of small pelagic fishes and the relative low occurrence of shoals. This result has to be related with the need for concentrating fish tactics. Setting of the nets takes place at night and the concentration is rather slow.
- They give a first stratification for biomass in Java Sea which fits well with what we know about fisheries' dynamics.
- They give very useful information on vertical distribution and circadian cycle; these results would not have been obtained without the input of echoprospections.
- They demonstrate the seasonal variability of biomass which explains the shifting of seiners to South China Sea fishing grounds at the end of the wet monsoon.
- They show that there is a strong correlation between biomass densities and salinities in confirmation of biological hypothesis.

This Seminar will last three days and you have got the tentative schedule. It will consist of two main parts : Acoustics in Indonesia (and not only Java Sea) on one hand, and case studies outside Indonesia or general considerations on the other. We hope also to have an informal Round Table on Tuesday night, kind of brainstorming about future for acoustics in Indonesia. Of course the proceedings of this Seminar will be edited -- as soon as possible -- as for the two others -- and D. Petit, responsible for the organization of this meeting and for the edition of the proceedings will give you -- or confirm -- the specification for pages and time table.

Obviously this Seminar is already a successful one, as it was not obvious to have so many scientists with skills in such a specialized field. Moreover obviously it will be a very successful one if the coming discussions involve really other fields as environment, bioecology, exploitation and management.

The project funded by European Union, funding which is due to end on next 30 of June, was for me a very exciting experience. We, ORSTOM scientists, are used to work for Development through Upstream Research and usually when it is time to apply or to get to more technical issues, other people take our material and results (it means it has to be given in proper understandable ways). Here we had everything from more fundamental and/or specialized research to technological innovations and I think it was a very positive process.

It would have been very negative to end sharply with all these activities. It is to be hoped that, as already stated by CRIFI and ORSTOM representatives, Pelfish will continue in order to get the best valorization and transfer for all our results. Moreover, an extension Project, dealing with Technological Innovation, Fish Quality and Management, could be presented. These very important issues should find a specific project structure and funding, possibly through European Union ? And, looking in the near future we should have to build an even more global approach, not only pelagic, not only seiners but all fisheries and resources : systemic approach dealing with complexity and co-management.

Going back to our present cooperation, I will first thank *"Balai Penelitian Perikanan Laut"* and its successive directors Dr. N. Naamin and Fatuchri Sukadi for their open collaboration, further we have to thank *Pak* Sumitro captain of the R/V Bawal Putih and all his crew.

My last words will be for the staff which allows this Seminar to be organized and take place here :

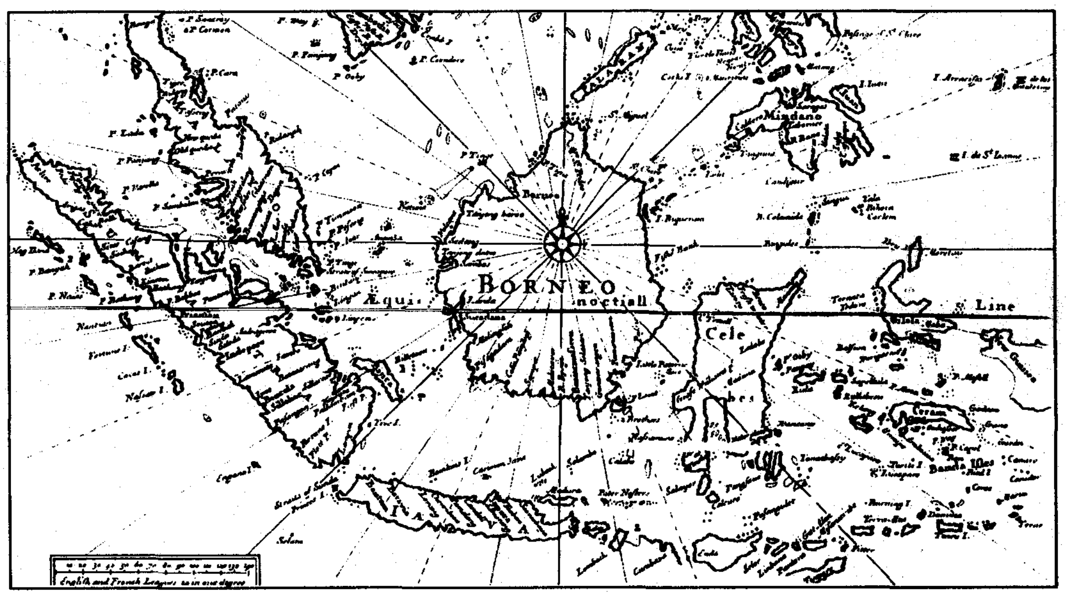
B.P.P.L. staff : Mrs. Hartati and Noveny, miss Sri;

PELFISH staff : Didier Petit, Pascal Cotel, Duto Nugroho;

and our two PELFISH secretaries : Elys and Ambar.

Part 1

Studies on Environment and Resources in the Java Sea area



THE PELFISH SURVEYS : OBJECTIVES AND DATA COLLECTION

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ABSTRACT

From 1991 to 1995, twenty acoustic surveys took place in the Java Sea and the surrounding areas in the frame of the PELFISH Project, sponsored by European Union, Indonesia and France. Their aim was to study the distribution, abundance and behaviour of the pelagic fauna, especially on the fishing grounds of the seiners. It needed various operations as environmental measurements, echo-integration, TS measurements, school localization, light attraction and trawl samplings. The scientific equipment and its adjustment, as well as the procedures of data acquisition used, are summarized (acoustic and physical measurements, samplings). The spatial, diurnal and bathymetric distribution of the sampling show that the data collection can give an accurate information for the prospected area. About 500 environmental stations, 1,500 TS stations and 20,000 density measurements give matter to constitute the basic information of a Data Bank which may be consulted at the RIMF BPPL, Jakarta (INDONESIA) or at ORSTOM, Montpellier (FRANCE).
KEYWORDS : acoustics, echo-integration, Java Sea.

ABSTRAK

Dimulai pada tahun 1991 hingga 1995, sejumlah dua puluh kali pelayaran akustik telah dilakukan di perairan laut Jawa dan sekitarnya melalui Proyek PELFISH yang biayai oleh Uni Eropa, Indonesia dan Perancis. Tujuannya adalah untuk mempelajari penyebaran, kelimpahan dan tingkah laku ikan pelagis terutama pada di daerah penangkapan ikan dengan pukat cincin. Hal ini didukung oleh berbagai aspek operasional seperti halnya pengukuran karakteristik lingkungan, echo-integrasi, pengukuran pekiraan ukuran ikan, keberadaan kelompok ikan, pengaruh cahaya serta pengambilan contoh melalui penangkapan dengan trawl dan kapal komersial pada saat survey. Peralatan ilmiah serta pengaturannya, prosedur sistem akuisisi data yang telah digunakan (akustik, pengukuran fisik,serta pengambilan contoh) akan disajikan dalam tulisan ini. Penyebaran secara spasial, diurnal dan kedalaman berdasarkan pengambilan contoh memperlihatkan sejumlah koleksi data yang dapat memberikan informasi secara akurat dan harapan terhadap perikanan pelagis. Sekitar 500 stasion lingkungan, 1,500 stasion pengukuran besaran target, 20,000 unit pengukuran kepadatan sebagai bahan informasi dasar bank data dapat dikonsultasikan pada Balai Penelitian Perikanan Laut, Jakarta (INDONESIA) atau pada ORSTOM di Montpellier (PERANCIS).
KATA KUNCI : akustik, echo-integrasi, Laut Jawa.

The abundance evaluations of Indonesian pelagic fauna, by means of Acoustics, began 25 years ago. The first surveys were carried on by the FAO, with the R/V Lemuru in 1972-1976 (Venema, 1996). The development of investigations had been supported then by various international programs : the Jetindofish Project with the FR/V Jurong in 1979-1981 (Lohmeyer, 1996), the CIDA/FAO Indonesian Fisheries Development Project with the R/V Tenggiri in 1981-1983 (Johannesson, 1984), the Indonesian-Dutch Snellius Expedition in 1984-1985 with the R/V Tiro (Schalk *et al.*, 1990). But on the other side, the Indonesian Research developed its proper investigations with the R/V Bawal Putih I (Merta, 1976; Amin *et al.*, 1981; Uktolseja, 1981), the R/V Tenggiri (Amin and Nugroho, 1990), the R/V Baruna Jaya I (Amin and Nugroho, 1991). In 1985, after a first echo-integration survey in the Java Sea (Boely *et al.*, 1987) and the beginning of a cooperation in Fisheries Biology with the B.P.P.L. in 1987, the PELFISH Project started in 1991. Its aim was the study of the fishing activity of the seiners in the Java Sea. It was sponsored by European Union, Indonesia (the Agency for Agricultural Research and Development, AARD) and France (the French Research Institute for Development through Cooperation, ORSTOM). The researches were focused on offshore pelagic fisheries, with the following objectives : provision of scientific advice for a future management, improvement of the performances of the fishing system, evaluation of the socio-economic impact.

Thus, to reach these objectives, PELFISH has developed various fields of activities and among them, studies oriented to the fishery functioning, bioecology and fish population dynamics. In this field, the aspect of the fish behaviour and the biomass estimation throughout the echoprospecting and echo integration were considered to occupy a special attention. Yet, the biomass evaluation by Acoustics is the only method able to supply the necessary information on the condition of the stock and its availability at any time. But, it appears that the method could bring up the more interesting information, especially in the studies on structures, distributions and behaviours

OBJECTIVES OF THE PROJECT AND CONSECUTIVE SCIENTIFIC ACTIVITIES IN ACOUSTICS

The objective, as expressed in the original Work Plan (Boely and Cholik, 1991), was that the Project was aimed "to study and improve the exploitation and the organization of offshore pelagic fisheries in the Java Sea ..." Especially, the Project aimed at promoting the development of offshore pelagic resources in the long term, "throughout a better knowledge on stocks, by suggesting better fishing methods as well as better conservation, handling, transformation, able to optimise the profits..." Translated in scientific terms, the investigation's subjects devoted to the acoustics research can be assembled into two principal terms :

- the study of the distribution and the abundance of the pelagic fish populations,
- the study of their behaviour.

These two studies had to be investigated through the two variables : time and space, in order to take into account the geographic and seasonal variations.

DEFINITION OF A STRATEGY

A strategy of prospecting has to be oriented from the available knowledge. At the beginning of the Project, exist few information : a possible existence of an "island effect" on abundance, observed in the surroundings of the Natuna Islands (Johannesson, 1984) and the necessary influence of a gradient in the west-east environmental characteristics on the pelagic populations in the Java Sea[1]. Especially, the presence of important catches in the North east of the Java Sea (Sadhotomo *et al.*, 1988; Boely *et al.*, 1988).

[1]Not forgetting the information given by the R/V Lemuru surveys made in the Java Sea, but unfortunately, these latter were still in a qualitative aspect.

Admitting that fishermen operate in the most accessible rich sectors for profitability, the orientation of research towards intensive fishing grounds as a priority was justified.

The Java Sea (Fig. 1) has a surface area of some 440,000 km^2 (Durand and Petit, 1995). From Semarang, the port of registry of the research vessel, the vast fishing grounds (Masalembo-Matasiri Islands) are at about 300 nautical miles. Besides, the trawler Bawal Putih I, at the Project's disposal did not present anymore satisfactory capacities -- with an autonomy of twelve days and a speed of 6.5 knots about -- to insure large surveys.

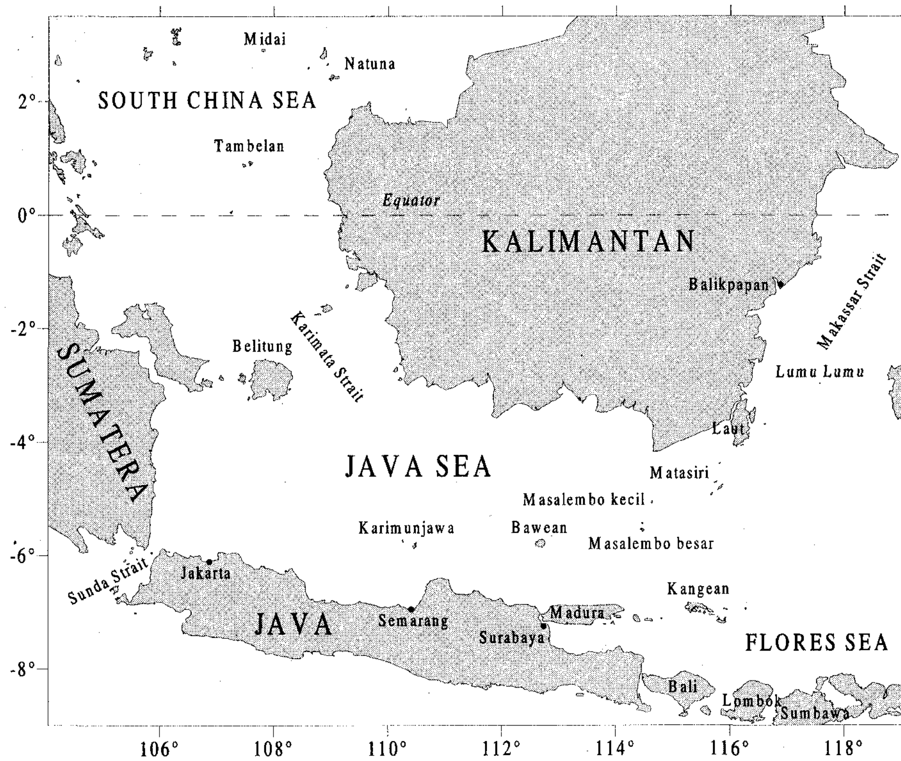

Figure 1 The Java Sea and its surroundings.
Gambar 1 Laut Jawa dan sekitarnya.

In a first time, the best way to associate the previous requirements and/or hypothesis in the prospecting scheme, was to run a transect from island to island through the intensive fishing zone, repeating the course adopted by the seiners to reach the richest fishing grounds. In this way, we were able to locate precisely the seiners in activity, sample them and compare the abundance in and off the fishing areas. When have been gained ship improvements (main engine, radar, GPS,...) and complemented the scientific equipment (trawls, netsond), more ambitious surveys have been carried out. Thus, the operations of investigation have been composed in two phases : until 1993, took place surveys to study mainly the seasonal variation along transects; from 1993, some large surveys and experiments complementing the precedent observations have been tried. Nevertheless, the short autonomy and the low ability of the trawler to sail have reduced the activities.

THE THEMES OF ACOUSTIC INVESTIGATIONS

Before the beginning of data acquisition in routine, two cruises (November and December 1991) were carried on to adjust the settings and controls of the acoustic equipment.

The domains of studies require different features of prospecting and observation (Simmonds *et al.*, 1992) and, during the Project, the various investigations set about can be gathered into 6 themes.

The description of the seasonal variation was mainly realized by transects from island to island from Semarang to Matasiri, when the weather allowed it. These transects took place 11 times from March 1992 to February 1994, especially in 1992 (Fig. 4).

Various local minisurveys ("mini," by lack of time) from 96 to 360 square miles, complemented the study of the local nycthemeral behaviour and gave information about the local day and night densities. All these minisurveys were located eastwards from Bawean Island (March, May, September, October, November 1992 and December 1993), on the fishing grounds of the Java Sea, except one, in April 1993, in the South China Sea.

Two large surveys covering the maximal area of the Java Sea, were achieved in October 1993 and February 1994. They allowed to have an overview of the density distribution and to evaluate the mean density of the Java Sea during the seasonal situations more or less extreme (Petit *et al.*, 1995).

Three cruises have been performed to describe local areas : in front of Semarang, in the coastal zone (April 1994), in the south eastern part of the Java Sea (May 1995), along the eastern continental slope (return from Lumu-Lumu Island, February 1995).

There were two exploratory surveys out of the Java Sea : a long transect through the fishing grounds in the South China Sea (April 1993) and a survey on the Kalimantan continental shelf in the Makassar Strait (January-February 1995). These two surveys were made when the fleets of seiners move out of the Java Sea for some months.

The last group of observations concerns punctual experiments as light attraction experiments in various places, close to or far from seiners (more than twenty experiments especially in May and November 1993), transects around the Matasiri Island (June 1992), Bawean and Karimunjawa Islands (June 1993), tracks around anchored *rumpon* (Fish Attracting Device, May 1993, November 1993), experiments on light effect during prospecting and some other methodological observations (effect of pulse duration, tilting of paravane).

We have to add to the precedent list the necessary tests of calibration, made at anchor in the Dungos Bay (Bawean I, by 17 m deep), well protected but far from Semarang, and Target Strength measurements on living fish at Bawean and Matasiri Islands (November 1991, October 1992, December 1992; Cotel and Petit, 1996).

Since November 1992, a new radar has allowed to locate the seiners met during the surveys and to study the relation between the fishing tactics and the distribution of the fish density (Potier and Petit, 1995; Petit and Potier, 1996; Potier *et al.*, 1997).

THE COLLECTED DATA

Environmental observations

From May 1992, the R/V Bawal Putih 1 has been equipped with a SEACAT SBE21 surface thermosalinograph and above all, a C.T.D. SEACAT SBE19 Profiler. During all the following surveys, vertical profiles of temperature, salinity and light penetration were executed along the tracks of echo-integration. More than 500 environmental stations were stored and analyzed.

Biological samplings

Tentative to rig the R/V Bawal Putih 1 with a seine in February 1993 did not give full success by inadequation of the ship. Besides, the aggregations met in the Java Sea, scarce and small, did not allow the opportunity to sample effectively the pelagic fish. From April 1993, a pelagic trawl (vertical opening 10 m), equipped with a Furuno CN8 netsond without cable and a bottom trawl (vertical opening 4 m) has been used. The abundance of the catches, except for bottom fish, stayed very poor and low significant.

Thus, when it was possible, the samples were the seiners met along the tracks. The species were determined and measured on board (weight and fork length).

Some other catches, made with trammel nets upon the bottom or near the surface were experimented with some success during the light attraction stations (November 1993), thanks to the presence on board of the Captain Guegen. But, due to the big dispersion of the pelagic fish and its escape, the whole of the cruises suffered of undersampling, and during the light attractions, when fish were well aggregated, the operational conditions did not allow us the sampling which needed the partnership of another ship.

Acoustic data

The diagram (Fig. 2) gives the representation of the scientific installation on board. Two sets of data were acquired with a Model 102 Dual Beam echo-sounder (BioSonics Inc.) working with a 120 kHz frequency. It was equipped with a paravane, towed aside the board and immersed at 1.5 or 2 meters deep. This type of equipment, semiportable, therefore more adaptable, made the various operations easier (prospecting, stationary stations and especially the calibrations) and storing the equipment in good condition, at land as well.

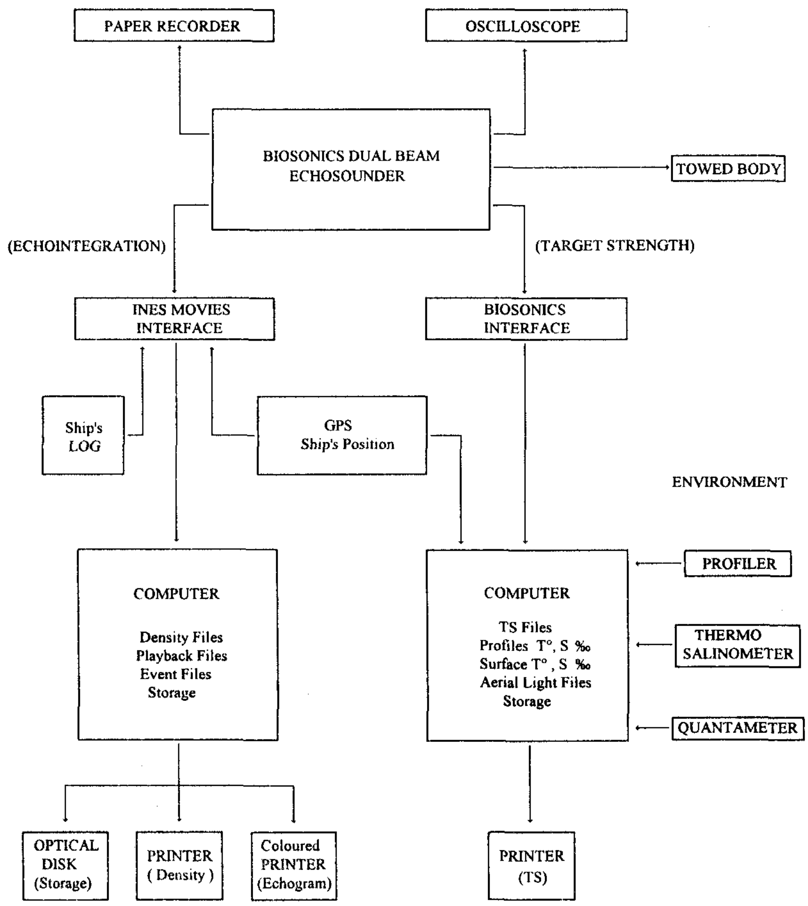

Figure 2 **Block diagram of the main equipment and data acquisition aboard the R\V Bawal Putih I.**

Gambar 2 **Diagram blok peralatan dan akuisisi data pada K.M. Bawal Putih I.**

Density measurements

They are automatically computed by means of an Ines-Movies system (Diner, 1991). The Ines interface is connected to the 10 kHz detected output (20Log function) of the echo-sounder and to a Ben log which measures the speed and to a computer. This latter gets the location given by a GPS.

In the interface, the signal of the echo-sounder is adjusted in voltage, amplified, digitized (7.5 kHz frequency) and squared. Thanks to a set of adjusting menus, the software MOVIES assumes the echo integration by distance, here the nautical mile, for echoes higher than a threshold and manages the input-outputs, from the GPS and the keyboarding, to the printers and the file storage. The integration range is from 2 m deep to the bottom, by layers of selected thickness (10 layers related to the surface, 4 related to the bottom).

During the surveys, the same sets of adjustments were generally used and were recorded in the stored files. Nevertheless, due to the low level of the detection, the threshold was a little more accurately adjusted during the cruise of December 1992, passing from 42 mV_{rms} to 33 mV_{rms} (echo-sounder output) for the following surveys.

Some measurements of density by surface have been used for the data processing in the PELFISH results (but the measurements of density by volume, or volume back scattering strength, are also available in the files). The mode of conversion of these data in weight is presented in another paper (Petit and Cotel, 1997).

At the end of an echo-integration track, the operator can have a set of information :

- a colour echogram,
- a listing of echo-integration data by nautical mile,
- a digitized signal data file, for playback,
- an echo-integration file,
- and a file recalling all events keyboarded during the track.

Due to the volume of information, the digitized data files need the use of a large storage system and along the PELFISH surveys, an optical disk storage was used for this purpose. All the information collected will be used to validate the data. The corrections of files are assumed by means of a specific software, OEDIPE (Masse and Cadiou, 1994) that allows also, among other functions, the configuration of data files in a format suitable with classical data processing software (Excel, Lotus, Surfer, Eva).

The Target Strength (or TS) measurements

Because the echo-integration goes on all along the tracks, another computer was used during the surveys. It allowed all other data acquisitions, as environmental data (by temporary connection to the Profiler or to the thermosalinograph) and especially the TS measurements by continuous connection with the echo-sounder (output 40Log function, Fig. 2). These measurements took place along the tracks, when the detection appeared abundant throughout the echo-integration monitor and/or at interval of three hours systematically. As for echo-integration, the data acquisition is realized by means of a signal processing board -- ESP (Echo Signal Processing) main board, housed in the computer. The echo-sounder output is interfaced with this ESP main board via the Signal Conditioning Pod (SCP), which also contains BNC outputs so that certain signals can be independently monitored. To perform the data processing, the user simply runs the appropriate BioSonics program. Although both softwares -- echo-integration (ESP-EI) and Target Strength measurements (ESP-DB) -- are available, only the ESP-DB program has been used for estimating fish Target Strength. This software also uses interactive menus, which permit a rapid and convenient entry of all processing parameters and multiple functions can be displayed on the screen. Individual TS measurements can be made by stratum, up to 100, from 1.2 m deep to the bottom. Each stratum can have its own size, voltage threshold, etc. They can be either surface-locked (numbered downward from the water surface) or bottom-locked (numbered upward from the bottom).

The data files, usually about 10,000 echoes for each observation, stored with the acquisition settings, can be used to perform the frequency distribution and vertical locations of the individual Target Strengths. Most of all, they are used to process the TS values in order to obtain average values then input as a factor in the final expression of echo-integration for biomass evaluation.

REPRESENTATIVENESS OF THE PELFISH ACOUSTIC SAMPLING.

Before the presentation of the results, we will try to give, from the lot of sparse data, a synthetic view about the sampling distribution. It is important to estimate the level of representativeness of sampling in relation to the geographic and seasonal environment studied. The geographic limits of the Java Sea used here are the ones defined previously (Durand and Petit, 1995) : in the north-western part, south of 3° S; in the north-eastern, south of 4° S, and the continental slope (100-200 m depth) on the eastern border.

The seasonal distribution of the surveys

In Java Sea, the dry season is the richest one for the landings and it was understandable that this active period of fishing might have been also oversampled. The monthly distribution of surveys (Fig. 3) shows a lack of sampling during 3 consecutive months. There are 2 reasons for that : the meteorological conditions and, crudely, the lack of manpower in the acoustics team. The first part of the dry monsoon has relative strong winds, not very favourable to surveys with a ship that is slow and pitching (the same circumstances explain the lack of survey during January). On the other hand, because of administrative holidays, the low number of acoustic team made impossible the survey programming at this period.

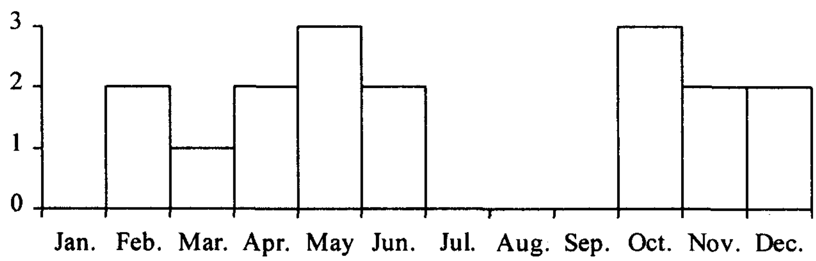

Figure 3 **Seasonal distribution of the PELFISH surveys.**
Gambar 3 **Survey akustik PELFISH menurut musim.**

The consequence is not so dramatic because the marine season being put back with regard to the climatic one, the "dry marine season" takes place in October-November. In fact, the difficulty to extract a seasonal follow-on in the PELFISH data is more the consequence of the observation dispersal, five years ago. The extreme situations were known, but the follow-on between them was less easy due to the high interannual deviations.

The distribution of samples in the nycthemeral cycle

To take into account the distribution of sampling between the diurnal and nocturnal phases is important. The PELFISH surveys, that have been covered without large interruptions show the behavioural difference of populations between the two phases. So, the coverage by day or by night, could only give the half of the information, as well as it could not put in a prominent position the specific presence of a nocturnal dense fauna. A precise counting of the day or night sampling has not been achieved but one can consider that the proportions are approximately similar. On the other hand, very few transects were repeated by day and by night, that gives the day and night comparison less accurate, but as it will see elsewhere (Petit *et al.*, 1995; Petit *et al.*, this book), the structural analysis shows that, regionally, the dimensions of these structures are more or less homogeneous and give permission to the partition of the Java Sea in 3 strata where the day and night comparisons are reliable.

One can only regret that the more frequent route Semarang-Matasiri Islands has been run with the same diurnal schedule, but the departure from the harbour and its entry are difficult by night.

The spatial distribution of sampling

Figure 4 represents, more or less, all the echo-integration routes made along the PELFISH Project, in the Java Sea. One can see, at once, that the surveys are denser in the eastern part. It is the consequence of the Project orientation, aimed in priority to study the seiners and therefore, their operating zones. The coverage is not at all homogeneous (Fig. 5). In the East of 108° E, there was only one survey (May 1995), and the northern part of 4° S has not been prospected.

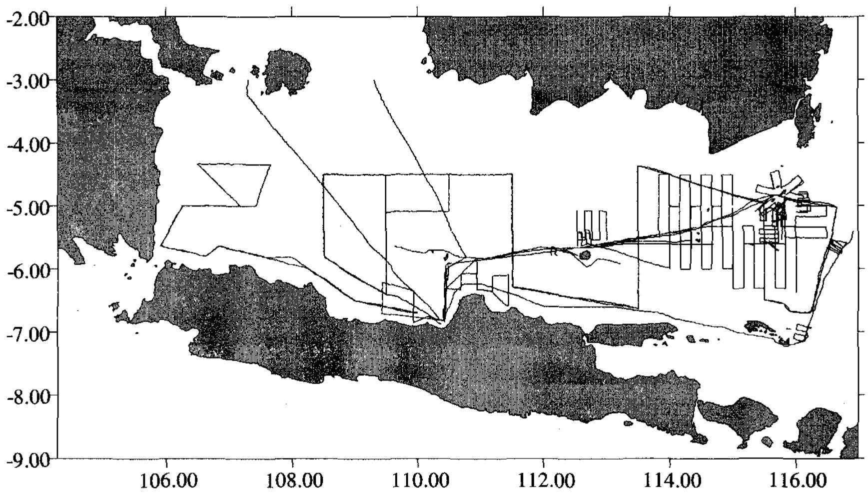

Figure 4 Tracks of the PELFISH acoustic surveys in the Java Sea.
Gambar 4 Jalur survey akustik yang dilakukan PELFISH di Laut Jawa.

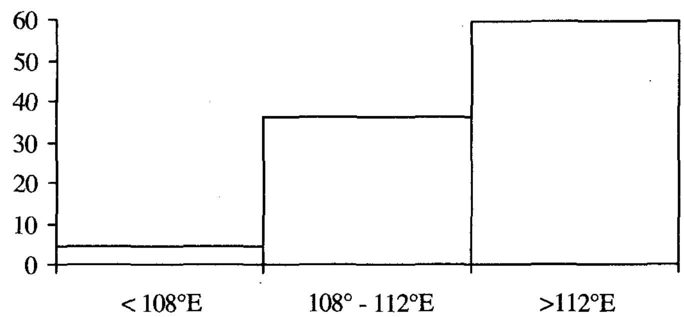

Figure 5 Localization of integration samples related to their geographic location.
Gambar 5 Frekuensi jumlah pengamatan akustik berdasarkan lokasi.

Though this sampling strategy would have been questioned during the Akustikan I workshop, this latter happens to be justified throughout the fish overdispersion pointed out, at least, in dry season. It was logical, in a first approach, to intensify the investigations in the eastern part. Thus, the observations and evaluations made will concern only the covered areas and other prospecting will be useful in the North and also in the South-East to extend the current conclusions. On this subject, the latter zone of 20,000 km^2, more or less, could allow a fishing ground extension, if the classic gears could be adapted to the local conditions (depth more than 60 m, currents). For the moment, the depths more than 55 m seem to be relatively underexploited, but as it will be seen below, they represent more than 25% of the Java Sea and quite the half area of the actual fishing ground.

Sampling and bathymetry

All the continental shelves present a zonation of their fauna related to the interaction between the continental factors and the bathymetry (particularly the light penetration and the pressure effect). The Javanese basin does not elude the rule, with the freshwater and alluvia brought in the surrounds and the oceanic water entry on its eastern border.

To analyze the bathymetric distribution of sampling relative to the respective areas of the Java Sea, the data distribution given by Pauly *et al.*, (1996)[2] was used. Figure 6 shows a good enough concordance between the two distributions. Only the stratum 10-20 m depth, extensive in the northern and western parts has been undersampled. But, these places are the domain of fishing customs, quite specific and the presence of many dead gears makes difficult the prospection with a large ship.

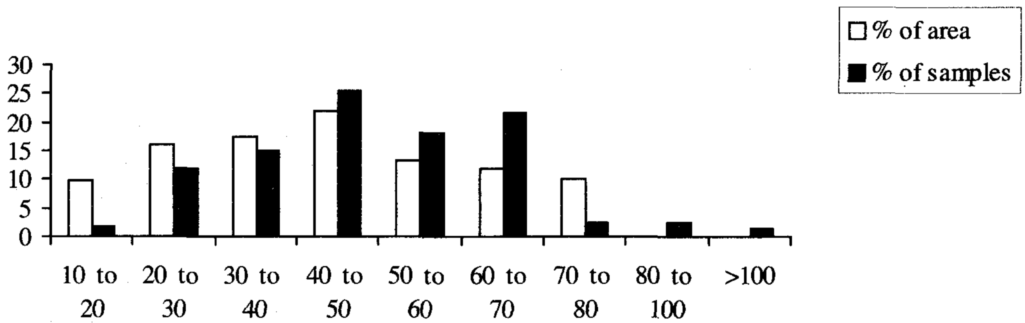

Figure 6 **Localization of all integration samples related to the bathymetric areas.**
Gambar 6 **Daerah pemgambilan contoh echo-integrasi menurut kedalaman.**

CONCLUSION

Until recently, there was not much information about the richness of the Javanese pelagic fauna and its behaviour (as well as about the seasonal oceanographic conditions), even if the pelagic fish catch has an important economic role (Potier and Sadhotomo, 1995; Roch *et al.*, 1996). The acoustics surveys of the PELFISH Project tried to make up lost time. These surveys were based on precise objectives, which aimed at complementing the information collected by the dynamicians and biologists operating directly from the exploitation, not to bring up an overall census of the Java Sea pelagic fauna.

Developed towards the stock evaluation, the acoustics techniques are capable to give information about size composition of the global resource as well as its distribution in relation with the environmental conditions provided that these latter are studied simultaneously. The quick analysis developed above shows that the sampling in its whole, was adjusted to the objectives and allows to provide a relatively good description on the main aspects of the seasonal evolution and related behavioural changes. Of course, the information collected is still inadequate and needs to be complemented by new prospecting, especially on the critical seasonal intervals, with large and consecutive surveys (January-February; May-June; September-October). This could be undertaken only with an efficient ship of 35 m length about, moving at 8-10 knots speed and about 20 days of real autonomy.

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[2] In our evaluation,we excluded the area of 0-10 m depth and we noticed that the given eastern surfaces correspond to the ones until the continental shelf.

Thanks to new implemented technologies, the scientific information collected allowed to create a Data Bank for more than 500 environmental stations, about 1,500 stations of TS and 20,000 miles of density measurements. The "know-how" to use this Data Bank and its content has been presented in a previous paper (Petit *et al.*, 1997).

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DISCUSSION

(Chairman Dr. PASARIBU)

Mr. MUNANDAR

Q : - I have two questions. The first one is about the gridding. From the cruises in 1992 until now, you have made arbitrary trips that look like gridded linear courses. Should not it have been better to integrate data from rectangular grids or triangular grids ? The second one is : why did you use the INES MOVIES echo-integration system while you used the BioSonics equipment to measure Target Strength ?

A : - When the prospecting operations began, we had to define them according to the knowledge we already had on the environment and the fishing grounds; that is to say : first, to prospect these fishing grounds and second, to analyze their gradients. Wealso had to test the ship's performances.

It is obvious that large surveys with close transects would have been more profitable; but this was impossible. Thus, we have varied the objectives and the prospecting mode as well according to the surveys, because the study themes were numerous, e.g. assessment, distribution, behaviour related to the environment and the traditional fishing tactics. We have, therefore, performed one routine transect, surveys as large as possible regarding to the autonomy of the vessel, mini surveys and light attraction experiments.

To answer the second question, while the BioSonics system was giving satisfaction about the quality of the equipment and the measures of Target Strength, the INES MOVIES system was superior for the storage, the data processing and the printing of echograms. Moreover, the BioSonics system could not assume both echo-integration and Target Strength measurements in the same time, in a single computer.

Dr. Marchal comments : "It is not possible to perform in the mean time echo-integration process and Target Strength measurement with the BioSonics system. You have to choose between echo-integration mode and Target Strength mode. Of course, if you have two BioSonics Echo Signal Processing interfaces, you can perform both of them, but you have to buy a second interface system. Besides, I think performances are better with this configuration."

Dr. NURZALI

Q : - Why the concentration of cruises is higher in the eastern part of the Java Sea than in the western part or in the South China Sea ?

A : - The South China Sea was not the aim of the Project. We focused on the eastern part of the Java Sea because this part is the richest one. We have mainly prospected around Matasiri islands because they are the principal fishing grounds. Concerning the western part of the Java Sea, based on the assumption that if there were no many fishermen there, the reason might be the poverty of fish and we delayed the prospecting of this area. It was an a-priori, and therefore, we decided to survey in order to verify our former assumption. We made only one survey, in May 1995, which confirmed our supposition that the density values we met were the lowest ones found in the Java Sea.

Dr. Gerlotto comments : "I would like to make some comments on this matter because, of course, it is the most serious point we have to deal with on acoustic surveys. Surveying has two objectives : one is ecological and would require the description of the area; the other one is to measure the actual density within the Java sea. For density measurements, we need two kinds of data : one is the mean value and the second one is the precision of this mean value. Usually, it is very universal that both mean and variance depend on the highest values. If you have not a good sampling on the high value data, it may lead to big mistake on the data; but if you have a bad sampling on very low densities, it is not so dramatic, as far as the mean density is concerned. According to this, it was, therefore, a good strategy to focus a large part of the allocated effort on high density areas.

Now, talking about ecological surveys, it is different. Obviously, it might have been extremely interesting to have a complete survey of the whole Java Sea, with regular parallel transects. I remember, during Akustikan 1, we had a discussion with you, Mr Chairman, on the strategy of sampling for ecology. It is true that we need this kind of survey, but I guess, my colleagues didn't have the choice. The first constraint was the time allocated to survey. The question was the key question. Maybe the right answer is to say : we decide to focus more on density and precision measurements than on complete ecological surveys."

THE SEASONAL VARIATIONS OF SALINITY IN THE JAVA SEA

D.PETIT, P.COTEL, D.NUGROHO

ABSTRACT

The climate in the Javanese basin is a monsoon regime : dry from June to September and humid from November to March. In regions seasonally subject to substantial precipitation, salinity is one of the more important factors affecting the distribution and abundance of fauna. For this reason, stationary vertical profiles have been performed to measure the variations of salinity. These measurements took place during the acoustic surveys carried out in the Java Sea in the framework of the PELFISH Project. Two surveys covering the central part, the first one in October, the second one in February, supply spatial and bathymetric localization of different water masses. Other transects, from Semarang (Central Java) to the Matasiri Islands, all along the north coast of Java, towards the China Sea and on the Kalimantan continental shelf, complete the information. Three factors seem to control the seasonal dynamics of the waters : the local precipitation systems, the direction of the winds and the dissymetric topography of the basin. In the dry season (south-eastern winds), desalinization starts in the North which is less deep. Its progression to the South is made by vertical mixing. In wet season (north-western winds), it is also in the North that the desalinization begins, leading to a temporary inversion of the salinity gradient. The latter will then be restored after the front of precipitation has moved southwards. The return to the dry season leads to a homogenization of salinity. Inter-annual climatic variations seem important and make difficult to have an interpretation based on localized observations in time and space. There is an annual longitudinal gradient where the western part being more steady in salinity than the eastern one, but there is also a latitudinal dissymetry induced by the bathymetry and the northern origin of desalinization.
KEYWORDS : environment, Java Sea, salinity.

ABSTRAK

Iklim di laut Jawa mengikuti pola musim dimana musim kering berlangsung pada bulan Juni hingga September, sedangkan musim hujan pada bulan November hingga Maret. Pada perairan yang secara musiman dipengaruhi oleh curah hujan, salinitas merupakan salah satu faktor yang penting dalam perubahan sebaran dan kelimpahan fauna. Atas dasar keadaan tersebut, variasi salinitas berdasarkan ruang dan waktu di laut Jawa telah diamati melalui pengukuran pada sejumlah stasion pada saat survey akustik yang merupakan bagian dari kerjasama proyek penelitian PELFISH. Dua survey yang meliputi bagian tengah laut Jawa yang dilaksanakan pada bulan Oktober dan Februari menunjukkan adanya perbedaan pola sebaran massa air menurut ruang dan kedalaman perairan. Beberapa pelayaran pada kurun waktu yang berbeda dengan liputan sepanjang jalur Semarang menuju pulau-pulau Matasiri, pantai utara Jawake arah Laut Cina selatan dan perairan paparan Kalimantan melengkapi informasi tersebut. Tiga faktor diduga berperan dalam dinamika musiman perairan yaitu : curah hujan lokal, arah angin serta ketidak simetrikan dasar perairan. Pada musim kering (angin tenggara) proses peningkatan salinitas diawali dari utara pada perairan dangkal yang kemudian bergerak kearah selatan melalui percampuran tegak (vertikal mixing). Pada musim hujan (angin barat laut), proses penurunan salinitas juga dimulai dari utara dan kemudian terjadi pembalikan sesaat gradient salinitas yang selanjutnya terus bergerak kearah selatan hingga batas pengenceran oleh curah hujan. Berulangnya musim kering menyebabkan proses homogenisasi salinitas. Perubahan tahunan keadaan cuaca sangat berperan penting namun perubahan ini menyebabkan kesulitan dalam proses intepretasi yang didasarkan pada pengamatan lokal menurut waktu dan ruang. Gradient tahunan secara membujur terdapat di perairan ini dimana, salinitas perairan bagian barat relatif tetap dibandingkan bagian timur. Demikian pula terdapat ketidaksimetrikan menurut perbedaan lintang yang disebabkan oleh perbedaan kedalaman perairan serta proses penurunan salinitas yang diawali pada subperairan bagian utara.
KATA KUNCI : lingkungan, Laut Jawa, salinitas.

Limiting its extension from 4°00 S to the Makassar Strait and from 3°00 S to the Karimata Strait, the area of the Java Sea represents approximately 442,000 km^2 (Fig. 1, Durand and Petit, 1995). This sea of an average depth of 40 m and slowly sloping towards the East, is wide open at its two extremities, allowing exchanges with neighbouring basins. The whole region is subjected to monsoon system. A rather dry season with southern trade winds lasts from June to September. The rainy season, under the influence of north-west trade winds stretches from November to March. In Java, rainfalls reach 1700 mm, which represents an annual average on thirty years (Fontanet and Chantefort, 1978). But in the same interval, the annual variation reaches more than 30%. From June 1992 to May 1995, salinity measurements were carried out during acoustic surveys. They are used to outline the seasonal cycle of salinity.

MATERIAL AND METHODS

The presented observations concern the results of the vertical profiles of measurements carried out along Semarang (Central Java) -- Matasiri Islands transects during surveys in June, September, October, November and December 1992, two big surveys towards the east from 108°30 E (October 1993, February 1994) as well as three surveys : towards the China Sea (April 1993), on the eastern continental shelf of Kalimantan (February 1995) and in the south-west of the Java Sea (May 1995).

An autonomous CTD vertical Profiler SEABIRD was used; this probe measures the pressure, temperature and conductivity at each 50 cm approximately. The use of this appliance is easy. While the ship stopped, the Profiler is lowered slowly after stand-by at the surface for adjusting its thermal equilibrium. Measurements are stored within the probe and then transferred at the end of the cruise. Different softwares are used in the calculation of average salinity and representation of bathymetric sections (Petit *et al.*, 1997).

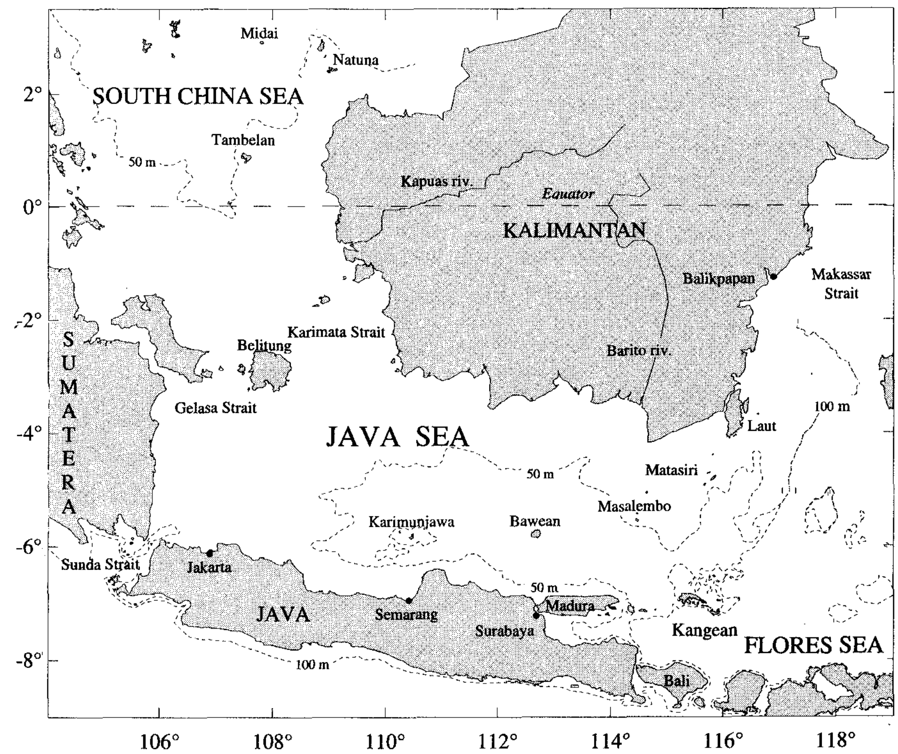

Figure 1 The Java Sea and its surroundings.
Gambar 1 Laut Jawa dan sekitarnya.

In full wet season

Java Sea

The February 1994 survey covered three quarters of the Java Sea on the eastern part (the deepest part). Figure 2 shows the distribution of hydrologic stations performed to obtain averaged salinity. The latter presents a decreasing gradient SW - NE, perpendicular to the axis of dominant winds. The values vary from 33.5 to 31.2‰, and the NW - SE diagonal of the Java Sea corresponds quite well to the 32.7‰ isohaline. On the Javanese coast, limited desalinization can be sensed only by the presence of a channel with the least salinity in front of Semarang.

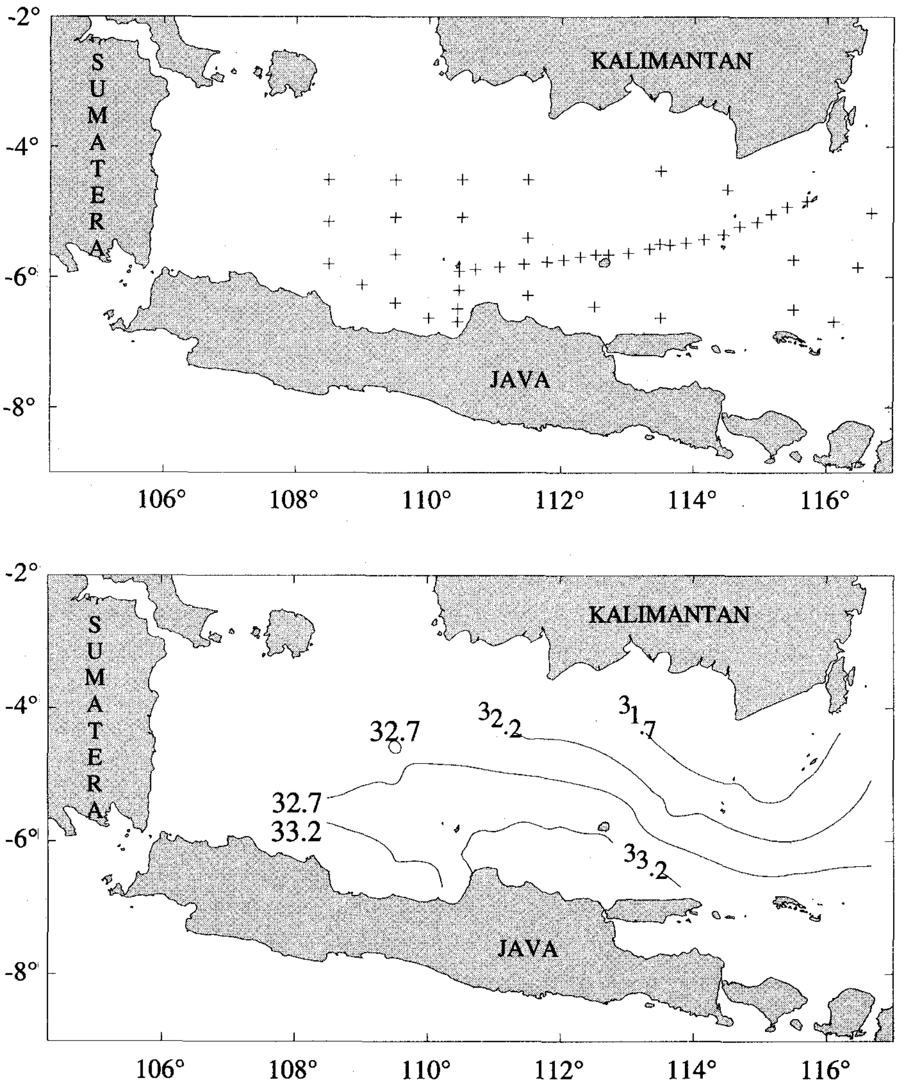

Figure 2 February 1994 (Survey 41) : Location of stations (up) and mean salinities (down) in the Java Sea.

Gambar 2 February 1994 (survey 41) : lokasi stasion (atas) dan rata-rata salinitas (bawah) di laut Jawa.

The northern vertical section indicates two sources of desalinization. One very important is in the East, of the Barito River, and acting until the South of the Java Sea (Fig. 3). The other less so is in the West, undoubtedly coming from the Karimata Strait. The median and south sections show that the more salinized waters (>33‰) continue toward the West. They are still linked in depth with the more oceanic salinities of the East (33.5‰). Below 40 m depth, the water stays above 33‰, up to 109° E.

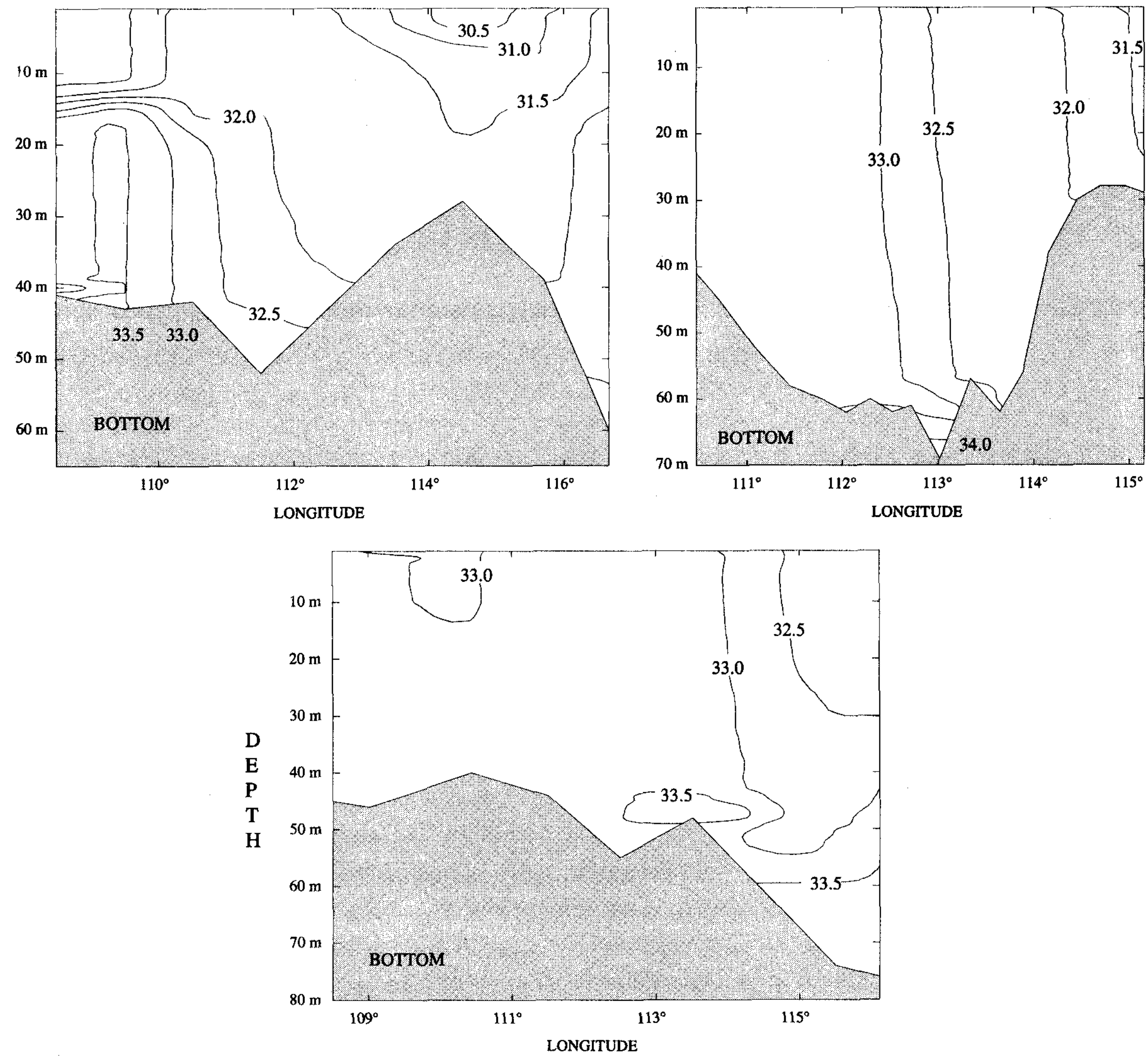

Figure 3 **February 1994 : Vertical profiles of salinity, north and medium sections (up), south section (down).**

Gambar 3 **Februari 1994 : Penampang tegak salinitas pada subperairan bagian utara dan tengah (atas) dan bagian selatan (bawah).**

Eastern continental shelf of Kalimantan

The February 1995 survey concerned the continental shelf of Kalimantan, in the Makassar Strait. The most coastal stations are situated at less than 25 miles from the shore. They show a marked desalinization in the North of Balikpapan and above all in the South (latitude of Pulau Laut, Fig. 4). The latter desalinization, 32‰ (Fig. 5), joins up with the one that stretches from Pulau Laut to the South, in February 1994 (31.7‰). But the major part of the plateau is still occupied by water which is above 32.5‰, on average. The northern flux is sufficiently important to limit the desalinization which remains coastal.

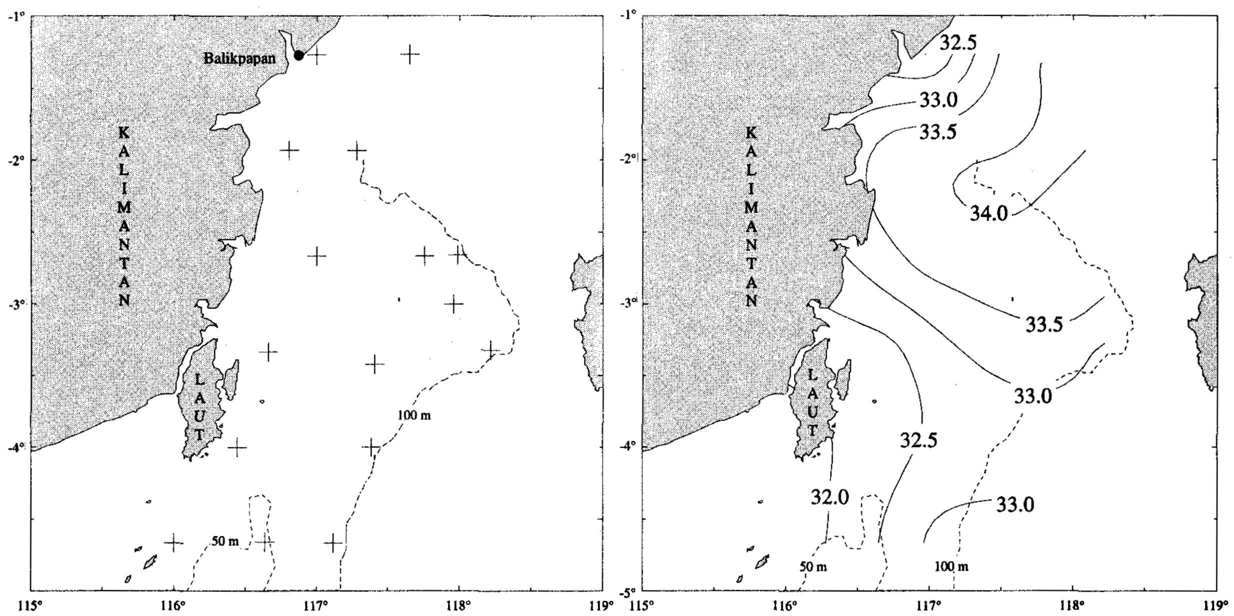

Figure 4 February 1995 (Survey 51) : Location of stations (left) and mean salinities (right) on the continental shelf of Kalimantan (Makassar Strait).

Gambar 4 Februari 1995 (survey 51) : lokasi stasion (kiri) dan rata-rata salinitas (kanan) di paparan daratan Kalimantan (Selat Makasar).

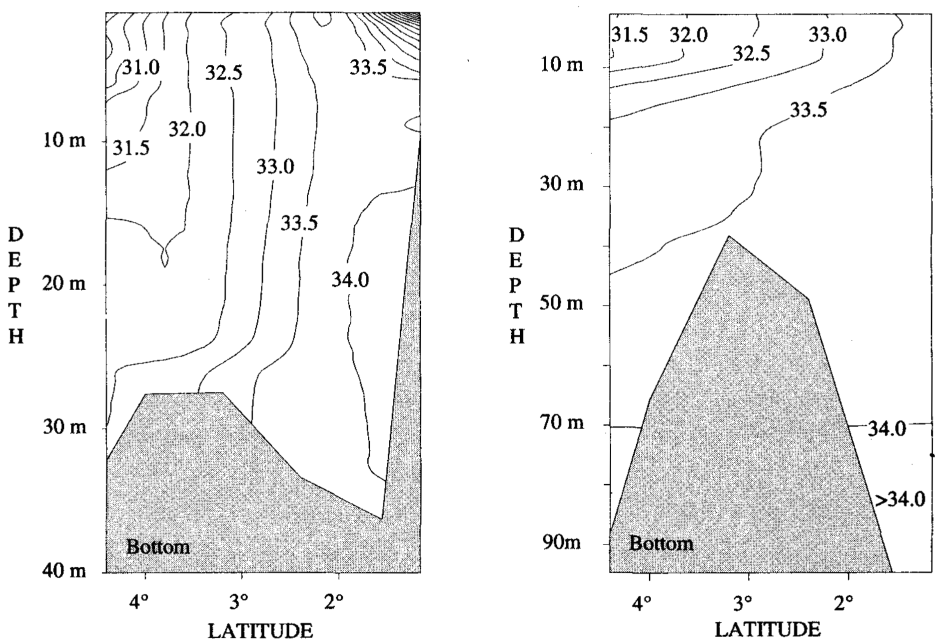

Figure 5 February 1995 : Vertical profiles of salinity in the Makassar Strait : left, along the coast, right close to the continental slope.

Gambar 5 Februari 1995 : Penampang tegak salinitas di Selat Makasar : kiri, sepanjang pantai; kanan, disekitar kelandaian daratan.

End of the rainy season

In the Karimata Strait

The April 1993 survey (Fig. 6) from Semarang to the South of the China Sea, gives the haline situation while the dominant winds are still slightly from the West and the surface waters still have a tendency to divert towards the Java Sea. The difference of average salinity between the Java Sea and the Karimata Strait is very slight. In the central part of the strait, the water is above 33.5‰, putting aside a desalinization at the latitude of the Kapuas River (Kalimantan), the average salinity drops only close to the Bay of Semarang.

According to the vertical sections (Fig. 7), the separation between the waters from the South of China Sea and that of the Java Sea is slightly marked (first twenty meters). But the ascent of the bottom up to 25 m depth by 4°00 S makes difficult the circulation of "bottom" waters, more salted, between both seas.

In the Java Sea, although the sampling is only represented by two transects, it seems that the haline situation has changed since February (Fig. 2 and 7) : at the longitude 110° E, the haline gradient to the North is reversed and there is, in April, a strong vertical gradient up to the North of the Karimunjawa Islands.

In the south-western Java Sea

Some observations were carried out all along the west Java coast, from Semarang to the eastern side of Sumatra, in May 1995 (Fig. 8). The representation of average salinities brings not much information : it seems that a slight gradient subsists all along the coast. The lowest salinities are found along Sumatra. By comparison with April 1993 survey, the average salinity of the northern stations is 0.5‰ lower. Also, it does not seem that there is an important entry of water through the Sunda Strait.

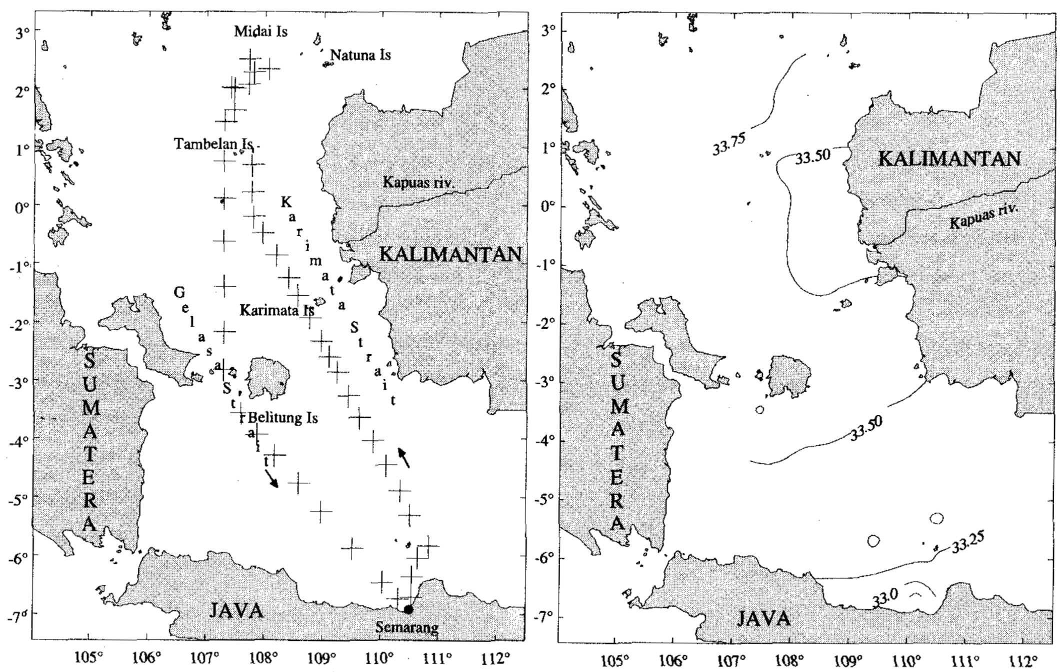

Figure 6 **April 1993 (Survey 31) : Location of stations (left) and mean salinities (right) from Semarang (Central Java) to the South China Sea.**

Gambar 6 **April 1993 (survey 31) : lokasi stasion (kiri) dan rata-rata salinitas (kanan) sepanjang jalur pelayaran Semarang menuju Laut Cina Selatan.**

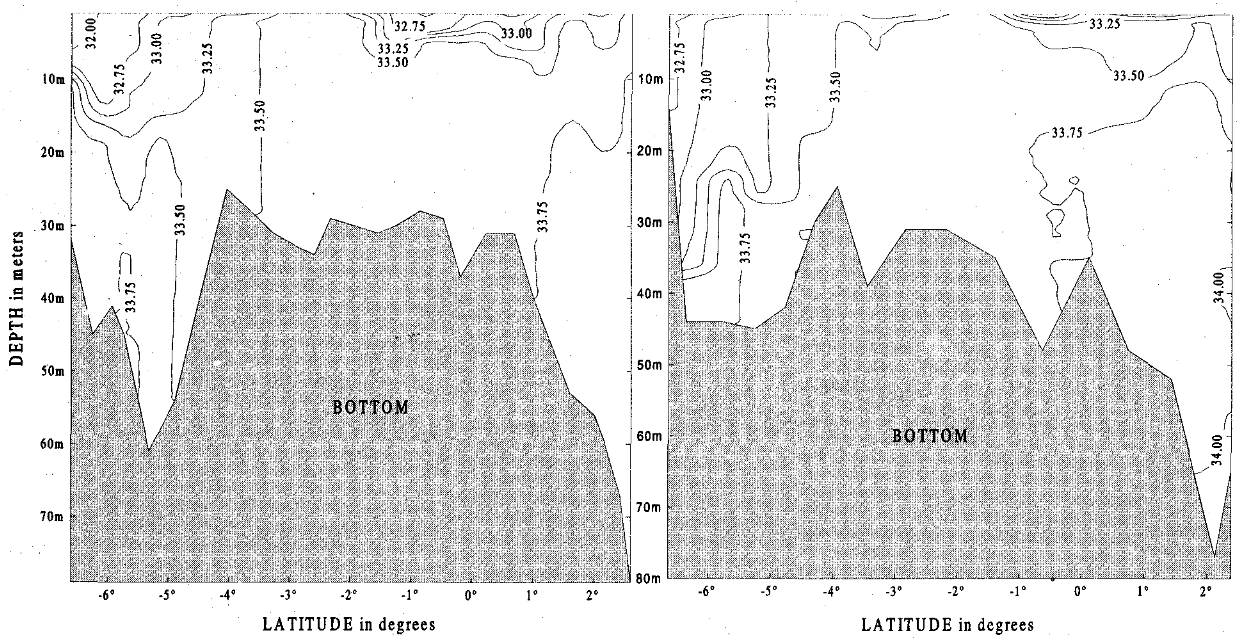

Figure 7 April 1993 : Vertical profiles of salinity, from Semarang to the South China Sea; left, one way by the Karimata Strait, right, return by the Gelasa Strait, ten days later.

Gambar 7 April 1993 : Penampang tegak salinitas pada jalur pelayaran Semarang ke Laut Cina Selatan (kiri) dan Selat Karimata (kanan) yang diulangi melalui Selat Gelasa 10 hari kemudian.

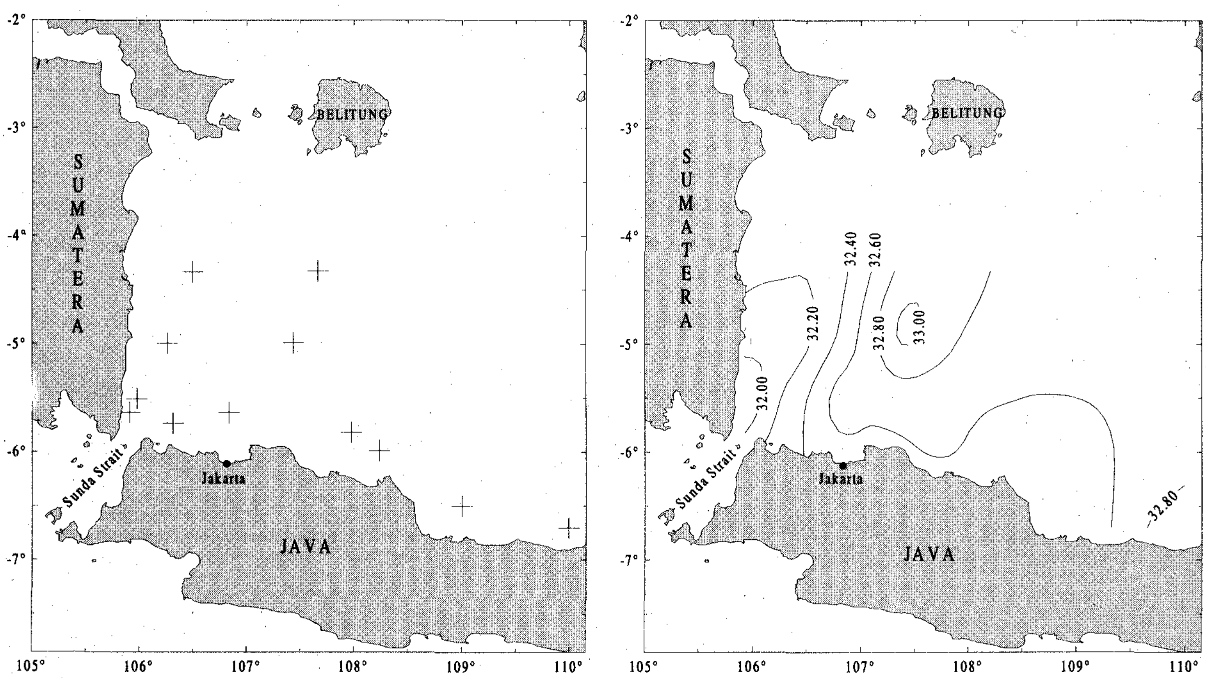

Figure 8 May 1995 (Survey 53) : Location of stations and mean salinities in the Southwest of the Java Sea.

Gambar 8 Mei 1995 (survey 53) : Lokasi stasion dan rata-rata salinitas di subperairan barat daya laut Jawa.

In the dry season

The stations during the survey of October 1993 had, more or less, the same location as the one of February 1994. Figure 9 represents the geographic distribution of average salinities. Practically the same orientation of isohalines can be found as in February 1994, but here the haline gradient NE -- SW is reversed. The 34.5‰ isohaline has more or less replaced the 32.7‰ isohaline of February. In the area covered by the survey, a slight desalinization remains along Java in the south-western part. Between February and October, the average deviations passed from 2.3 to 1.1‰.

The vertical sections (Fig. 10) indicate that the penetration of the water occurs above all, in the North, in the shallower part: the 34.5‰ reaches 111° E in the North, 112° E at the latitude of the Karimunjawa -- Bawean Islands, and is occasional in the southern part. According to the average salinity values, one can consider that the quasi-entirety of the water has been replaced, until 108° E.

The wet to dry season evolution along Karimunjawa - Matasiri transects

These transects, achieved in 1992, allow one to follow the evolution of desalinization.

In June (Fig. 11), the 32.3‰ isohaline is at 112° E, so quite east. The western values, less than 31.8‰, are lower than the ones met in precedent months (April 1993 : 32.7‰, in front of Semarang as well as in the west of Java, in May 1995). There is no longer a vertical gradient, likely because of a strong mixing.

At the end of September, the desalinization is well advanced. By 112° E, the 34‰ waters can be met. The deviation between salinities has not changed since June.

In October, the desalinization of the basin is at its maximum : the isohalines did advance to the West and the 34‰ waters reaches 111° E. But the comparison between October 1992 and 1993 shows that from one year to the other, the level of desalinization changes. In 1992, the 34.5‰ waters penetrated until 114° E, reaching 112° E in 1993.

One month later, the high salinity waters have already started their retreat towards the East. Waters, less than 33.3‰, arrived from the West. Doubtless, it concerns residual waters and that advance indicates that waters coming from the Karimata Strait began their entry into the Java Sea. By 112° E, it needs almost three months for the water to gain 1.7‰ in salinity and only one month to drop 1‰.

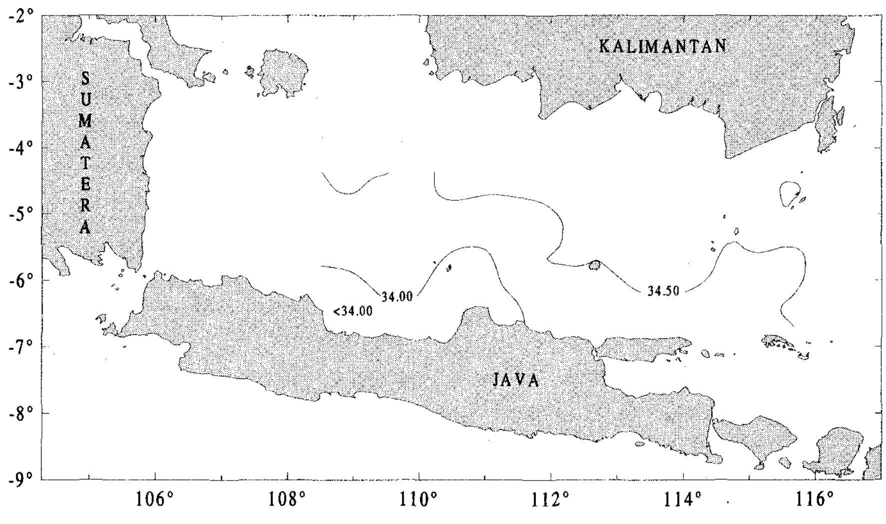

Figure 9 **October 1993 (Survey 34) : Mean salinities in the Java Sea (for the location of stations, see Figure 2).**

Gambar 9 **Oktober 1993) survey 34) : Rata-rata salinitas di laut Jawa (lokasi stasion tertera pada Gambar 2).**

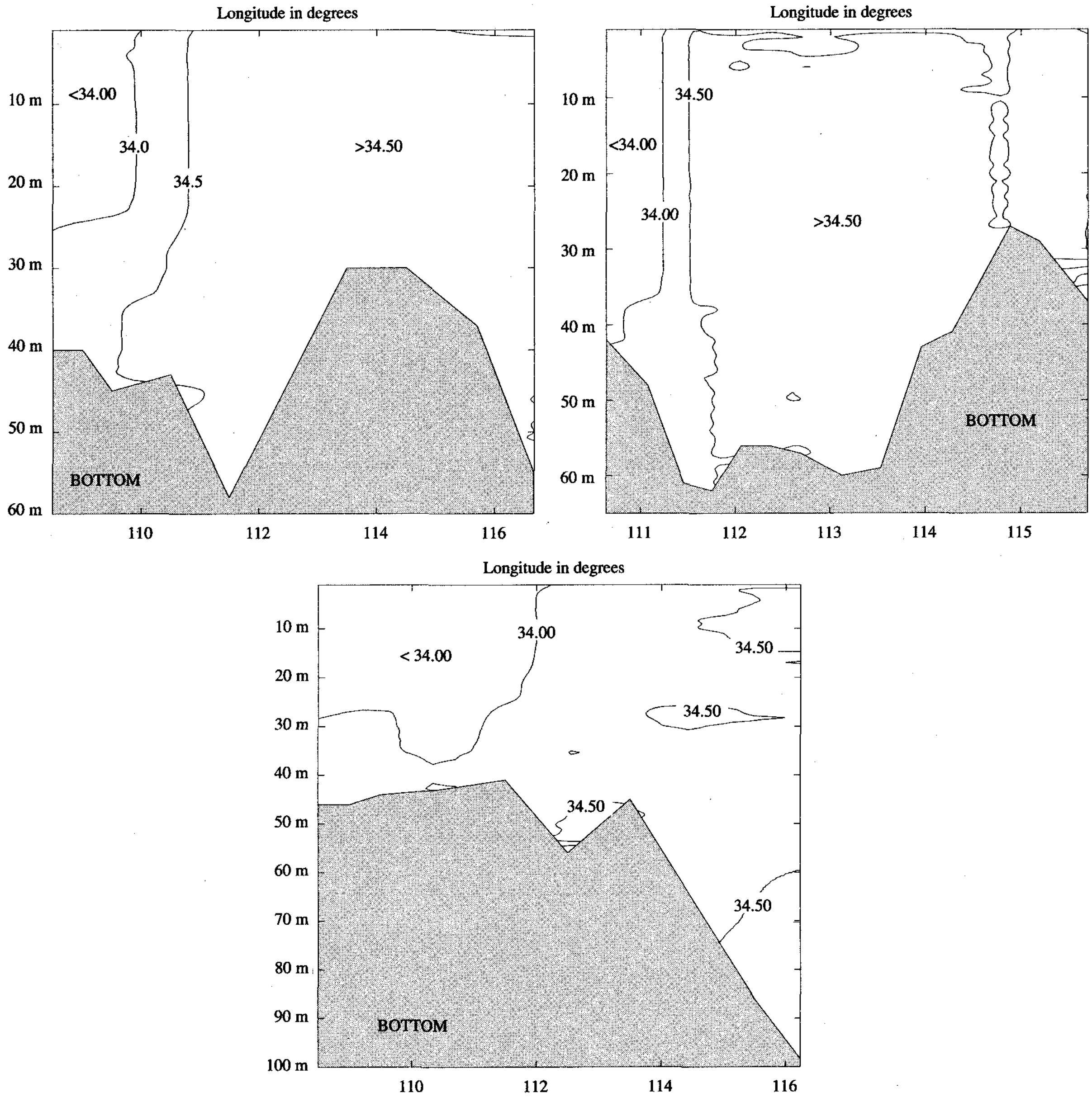

Figure 10 **October 1993 : Vertical profiles of salinity, up to down, north, medium, south section.**

Gambar 10 **Oktober 1993 : Penampang tegak salinitas pada subperaian bagian utara, tengah dan selatan (dari atas ke bawah).**

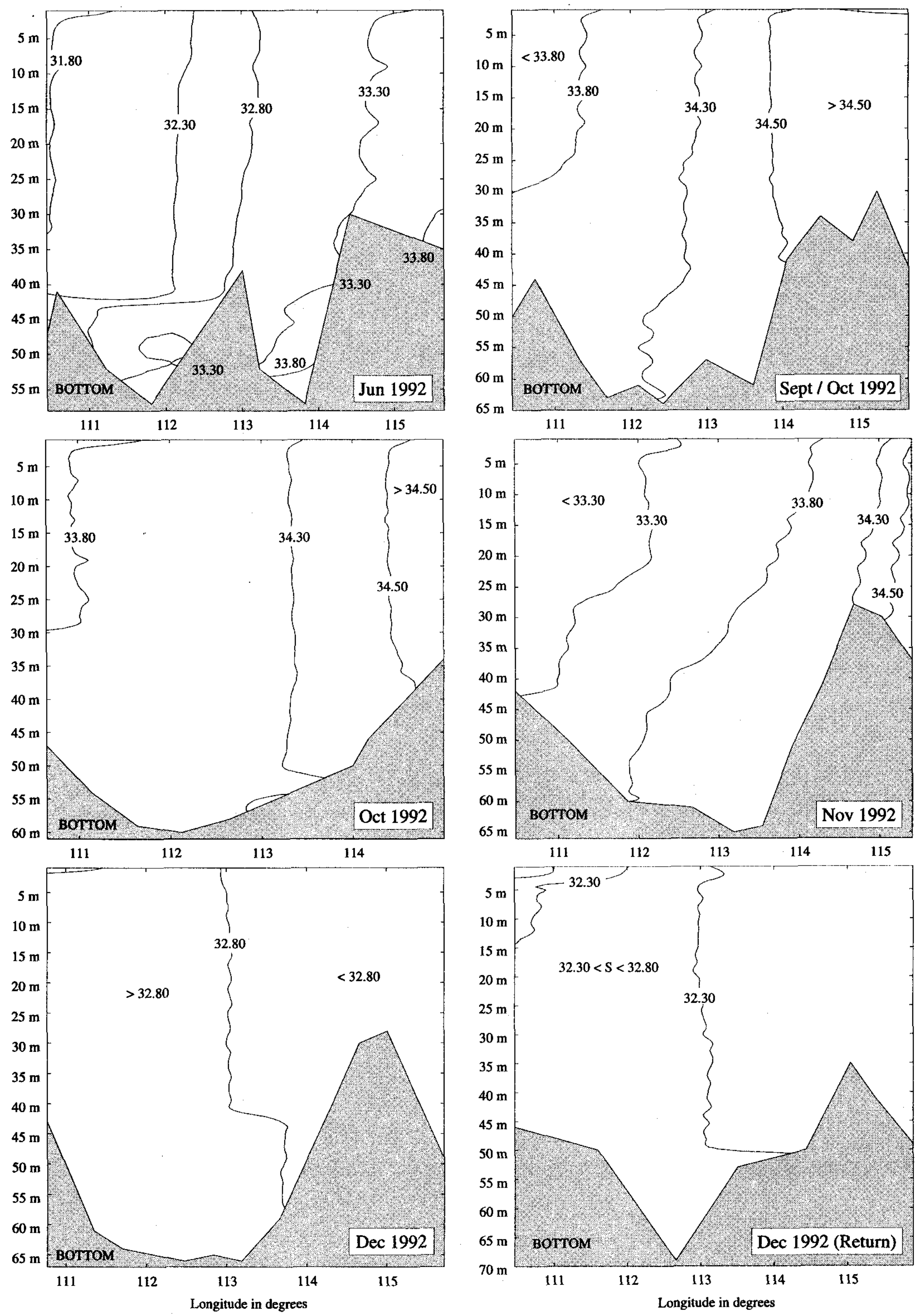

Figure 11 **In 1992, vertical profiles of salinity along the transect Karimunjawa - Matasiri Islands; the return in December took place 20 miles south of the one way.**

Gambar 11 **Tahun 1992. Penampang tegak salinitas sepanjang jalur pelayaran Karimun Jawa menuju pulau-pulau Matasari; pengulangan pada bulan Desember dilakukan pada jalur pelayaran 20 mil selatan sejalar jalur keberangkatan.**

On the December transect, the real desalinization appears, coming from the North and invade first the shallow zones, around the Matasiri Islands. That desalinization, pushed by west winds quickly gets through the middle of the Java Sea. At the return from Matasiri, the isohaline 32.8‰ is already located at 113° E south of the Bawean - Masalembo axis, isolating to the West, waters of 33‰. It is doubtless this pocket of more salted water that will be met in February on the north coast of Java.

CONCLUSION

The climate of the Java Sea is a typical monsoon climate (Veen, 1953; Fontanet and Chantefort, 1978) with a complete inversion of winds. The wet season, in the Java Sea, lasts from December to March with periods of strong wind (Potier and Boely, 1990) coming from the Northwest. Farther north (Karimata Strait), it begins earlier (October - November), following the southern movement of the atmospheric Inter-Tropical Front (Fontanet and Chantefort, 1978). The dry season occurs from June to September with more regular south-eastern winds. The impact of heavy rainfalls on Sumatra and Kalimantan linked with the circulation due to the wind during the wet season, and the one of the entry of oceanic water pushed by east wind in the dry season, were represented by Veen (1953) and by Wyrtki (1961). The two authors, using principally "ship" surface data, represent the movement of waters throughout the Java Sea, relating it to the regional environment by means of average isohalines.

The existing gaps in our observations, from 1992 to 1995, make it difficult to fully understand the haline mechanisms, all the more so since the phenomena seem a bit more complex than those previously described in a regional perspective. Wyrtki (1956) underlined the existence of important inter-annual variations joined to those of precipitation. They make difficult to get a seasonal description based on data acquired from several years. These variations have been indicated here, in April - May and in October. However, even incomplete, our observations permit a better knowledge of the seasonal evolution of the waters in the Java Sea.

Veen (1953) established that average surface salinity varies annually from 30.8 to 34.3‰ in the eastern part and is more limited towards the West, from 109° E, between 30.6 and 32.6‰. On the Semarang - Matasiri transect, the extremes were found in June (31.8‰) and in October (34.5‰); on the bottom by 30 m deep, the minimal value descends to 31.2 in February. There is thus approximately the same deviation along the vertical than in surface; the western part was not sufficiently prospected to present the values, but at the longitude of the Karimunjawa Islands, the seasonal deviation of 3-4‰, in the eastern part (February -- October), drops to 1.7‰ (June - October) only.

As Wyrtki said (1961), "the vertical curves of salinity show an almost homogeneous salinity from the surface to the bottom over the more shallow regions." The majority of the vertical curves show a quasi verticality of isoplethes. But in period of strong desalinization, important vertical gradients can appear before mixing, leading to local vertical deviations acting, likely, on the pelagic fish distribution (February, April).

Localization and evolution of the haline characteristics in the Java Sea seem influenced by three main factors :

- the regime of the rains on the side basins (abundance and period),
- the system and direction of the seasonal winds,
- the topography of the Java Sea basin.

This last factor, permanent, acts in the same way on the movements and the exchanges, whatever the annual variation of the others. Largely open to the East, the Java Sea communicates with the Karimata Strait by a section half the size. In period of north-western monsoon, the topography will not be opposed to the circulation of superficial waters. It is not the same in period of south-eastern monsoon where the exits by the strait attempt to limit the outcoming flow. This also can have an effect on differential movements of the fauna between the opposite seasons. In the East, the basin presents a dissymetric bathymetric topography between the North and the South (Durand and Petit, 1995), the sector close to Kalimantan being distinctively less deep. Well exposed to dominant winds when the rains become weak, it is in this zone, that the desalinization of the Java Sea will begin, by flow, while in the southern deeper part, it seems more related to a vertical mixing. Close to the first sources of desalinization, the northern zone will rapidly be invaded by the continental waters. This area presents the bigger annual haline deviations.

The progress of the marine wet season occurs apparently in three stages. From November, the lowering of eastern wind combined with the beginning of western wind, will progressively stop the desalinization and favour a return to the East of less haline stagnant waters from the western part. But, the precipitations also begin on the west borders of Kalimantan, east borders of Sumatra and in the Karimata Strait.

The real desalinization seems to begin in December. As a consequence of precipitations begun in November, it is going on towards the South and appears on our Karimunjawa - Matasiri transect by the East near the supply of freshwater (Barito River). The quick extension to the South is doubtless favoured by occasional inversion of winds. From the situation observed in February, one can see the consequence of this second phase : the isolation of a mass of higher salinity on the northern side of Java.

Unfortunately, the third stage has not been sufficiently observed. According to Wyrtki (1961), about one month goes by between the moment of maximum rain and its effect on the sea. So, he estimated that the maximum desalinization will take place in March. Soeriaatmadja (1956) showed obviously, by 5° - 6° S a surface maximal desalinization in February - March. The surface values reported as much by Wyrtki as by Soeriaatmaja are as a whole, inferior to those found during PELFISH surveys. It could suppose that in February 1994, the observed situation was due to lateness of precipitation. The few observations of April 1993 and May 1995 indicate that, in the third phase of desalinization, a « normal » salinity gradient -- a salinity increasing towards the centre of the basin -- is re-established. The major biological effect of desalinization in the Java Sea would occur later than the date of maximum precipitation leads to suppose : in May, when vertical homogenization is practically accomplished.

Wyrtki (1961) underlines the importance of exchanges through the Karimata Strait with the penetration of waters at 32‰, into the Java Sea, between January and June. One finds on the north section in February 1994 (Fig. 3), a tongue of 31‰ water which could be this trace. The survey of April 1993 shows that, at least certain years, waters of 33.5‰ can try to enter the Java Sea, especially by the Gelasa Strait. But what is the biological importance of this phenomenon ? At this time in the Java Sea, the waters are close to their maximal desalinization. The exchange would be weak, due to the shallowness of the strait; furthermore, it could not persist a long time with the next inversion of the monsoon winds admitting as Wyrtki, that, in the Java Sea, the current is the same in the whole water mass.

By comparison with the wet season, the desalinization of the Java Sea seems to be a much simpler phenomenon. According to the average situation of October, the « cleaning » of the basin will be intensively completed by the northern side, by flow and mixing.

In conclusion, the study of salinity variations, no longer limited to surface observations, corroborates the previous global conclusions. It also makes particular seasonal situations appear and better localize water masses. The Java Sea presents a W - E gradient of its environmental characteristics, the western part having lower haline variation than the eastern one. But, there is also a latitudinal dissymetry of the basin, because the southern part, deeper, keeps later higher salinities. Wyrtki noted that "these water movements may be expected to have considerable bearing on the movements of fish and their eggs and larvae." Potier and Boely (1990) showed the influence of the monsoon on the level of catch. Repeated short time observations at the beginning and at the end of the wet season could clarify the migratory movements and help to delimit the reproduction areas that have already been suggested (Sadhotomo and Potier, 1995).

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Discussion

(Chairman Dr. Pasaribu)

Dr. Merta

Q : - Regarding to Figure 2, showing the location of the oceanographic stations in the Java Sea, I wonder why ¼ of the Java Sea, the western part, has not been covered with stations. Some of stations are close together, some are lacking. The repartition doesn't seem consistent with a suitable oceanographic spread.

A : - Obviously, we should have better information if the western and northern parts (or more places) had been prospected. The problem we faced was to cover the maximum of the Java Sea in the short time of 12 or 13 days only. It was the ultimate autonomy of the research vessel. That is why we have selected this survey design which was covering more or less the most important part of the deep waters of the Java Sea. We have performed many profiles along the transect Semarang-Matasiri, because for us, it was the track of reference and we tried to obtain the highest description of this transect.

GENERAL FEATURES OF JAVA SEA ECOLOGY

B. SADHOTOMO, J.R. DURAND

ABSTRACT

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

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

ABSTRAK

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

Variabilitas iklim tahunan sebagaimana ditunjukkan oleh perubahan rataan curah hujan merupakan faktor eksternal yang berperan mengatur perubahan jangka panjang kelimpahan ikan pelagis kecil.
KATA KUNCI : Laut Jawa, lingkungan, ekologi, distribusi.

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

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

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

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

PHYSICAL FEATURES

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

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

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

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

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

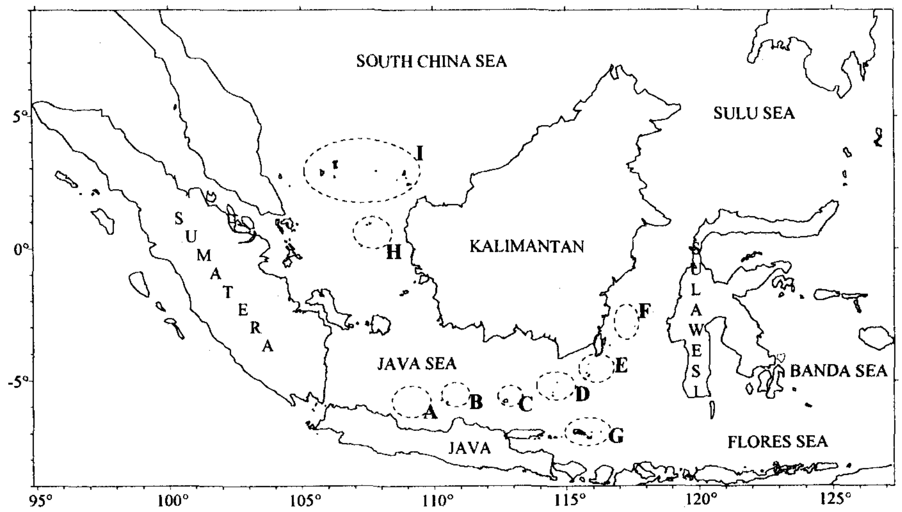


Figure 1 **Location of the fishing zones of seiners in the Java Sea.**
Gambar 1 **Lokasi daerah penangkapan purse seine di Laut Jawa.**

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

CLIMATIC FACTORS

The monsoon factors

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

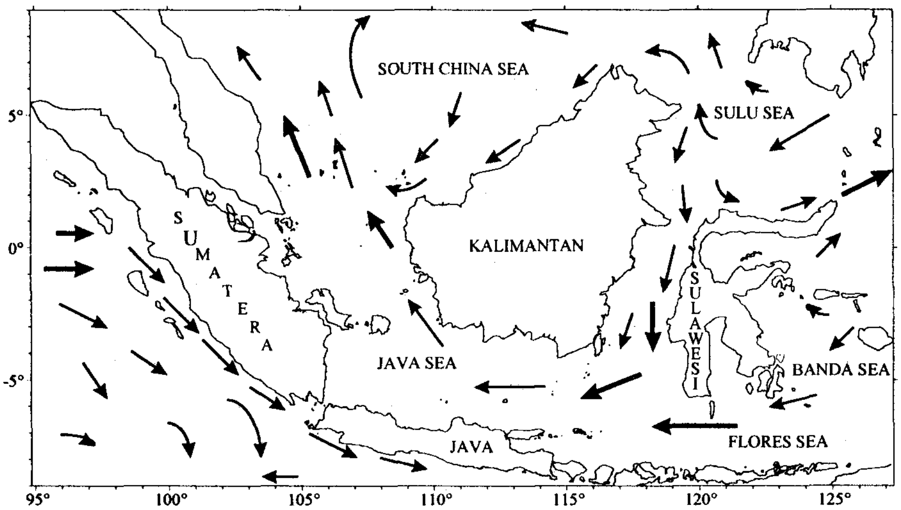
The monsoon clearly impacts a semestral change of hydrographic and atmospheric parameters that seasonally determine the sea water properties of the Java Sea. The surface currents tend to follow the direction of the prevailing winds which gradually change along the year. These wind-driven currents just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

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

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

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

A .South-East monsoon



B. North-West monsoon

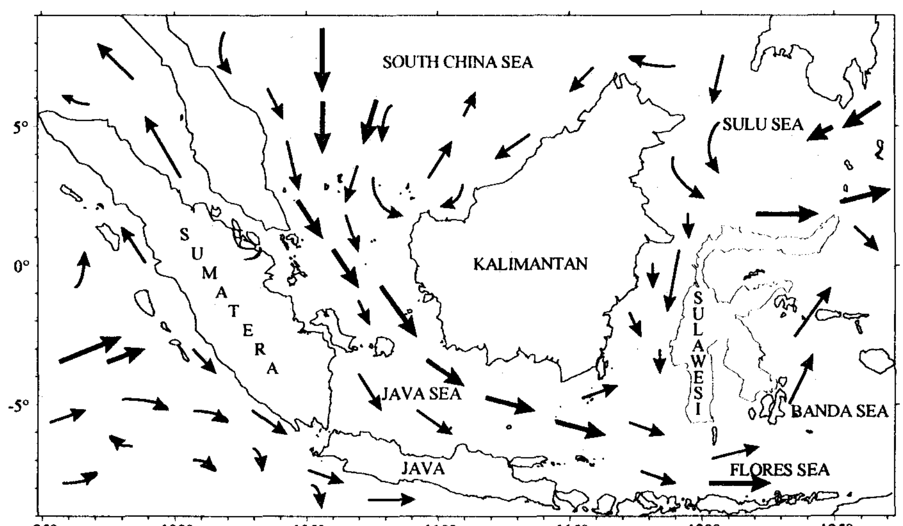


Figure 2 **Average current direction during North-West and South-East monsoons (from Wyrtki, 1957; 1961).**

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

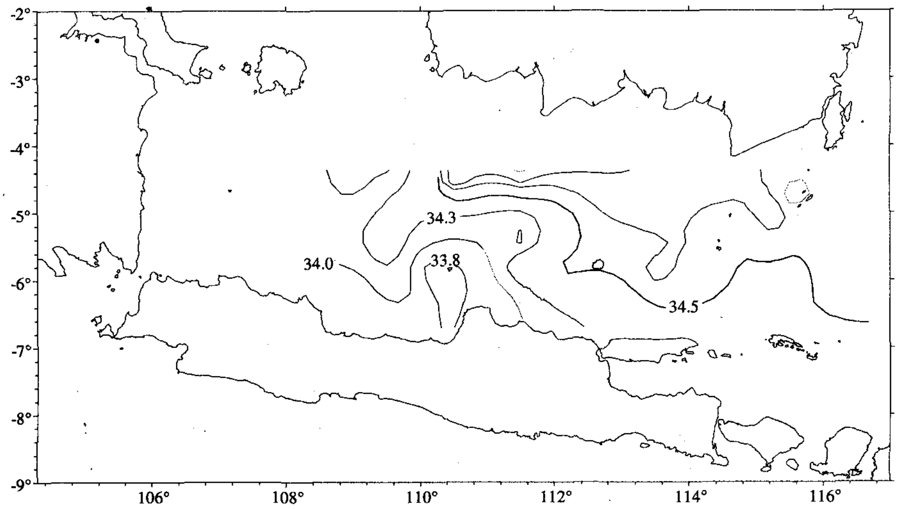


Figure 3 **Mean salinity contours observed in October 1993 (Cruise 34) showing the shifting of saline water from the East.**
Gambar 3 **Rata-rata salinitas yang diamati pada bulan Oktober 1993 (cruise 34) menunjukkan perubahan air asin dari Timur.**

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

Interannual variability

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

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

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

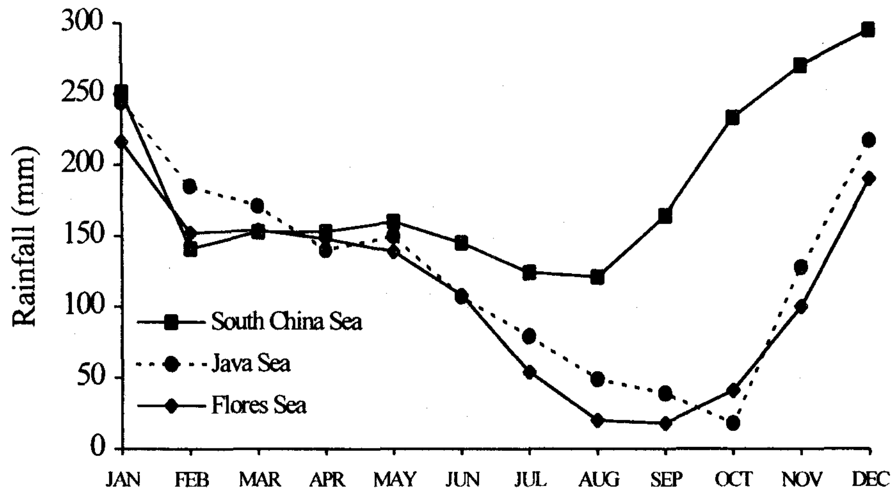


Figure 4 Rainfall at three areas (adapted from Wyrtki, 1956a).
Gambar 4 Curah hujan di tiga daerah (diadaptasi dari Wyrtki, 1956a).

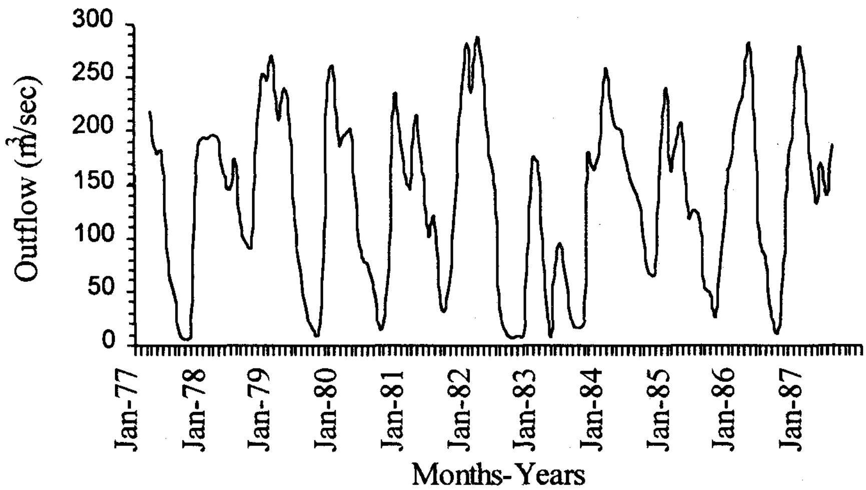


Figure 5 Monthly discharge of Negara River, South Kalimantan.
Gambar 5 Debit air bulanan dari Sungai Negara, Kalimantan Selatan.

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

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

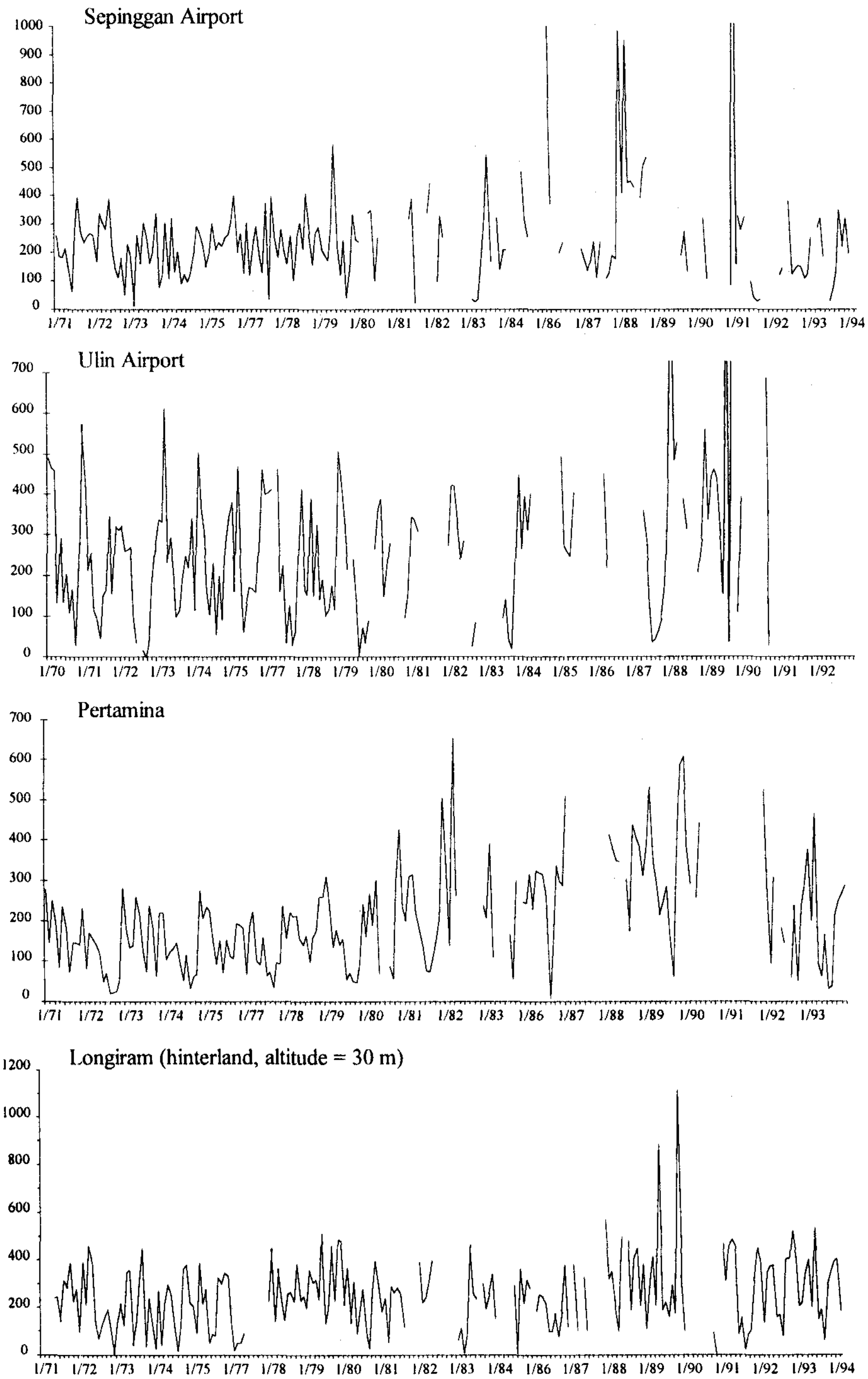


Figure 6 **Historical data of the rainfall recorded at four Kalimantan meteorological stations (Source: Agency for Meteorology and Geophysics BMG, Jakarta).**

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

Distribution of species and populations

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

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

Reproduction and fish size distribution

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

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

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

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

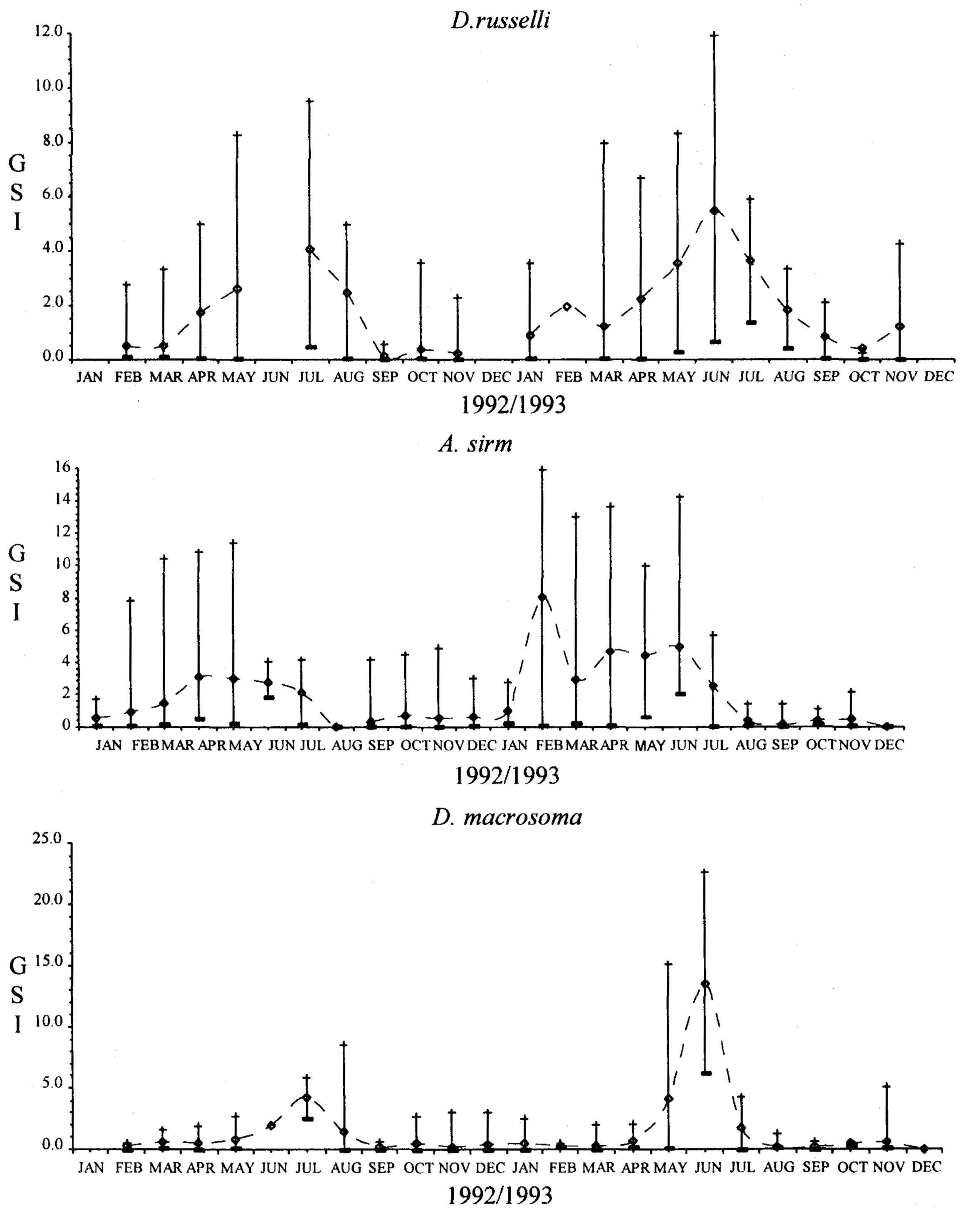


Figure 7 **Monthly evolution of Gonado-Somatic Index (GSI) and deviations for three main species in the years 1992-1993.**

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

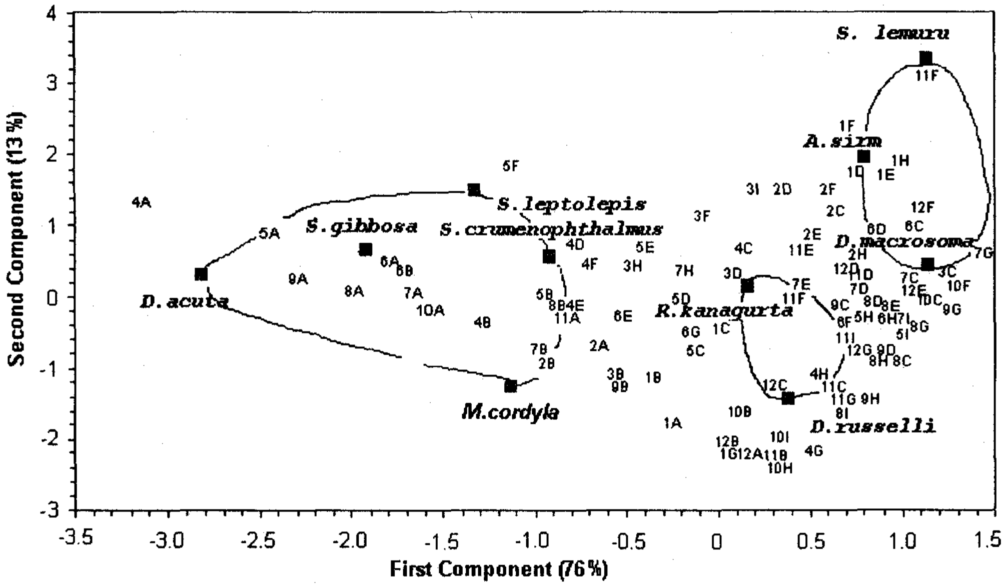


Figure 8 **Superimpose plot of species and monthly fishing zones using the weighted Principal Conponent Analysis (P.C.A.)(1 to 12, denote the months of sampling; A, B, C... are codes of the fishing zones as presented in the Figure 1.**

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

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

CONCLUSION

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

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

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

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

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

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DISCUSSION

(Chairman Dr. PASARIBU)

Dr. NURSALAM

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

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

Dr. NURZALI

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

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

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

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

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

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

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.

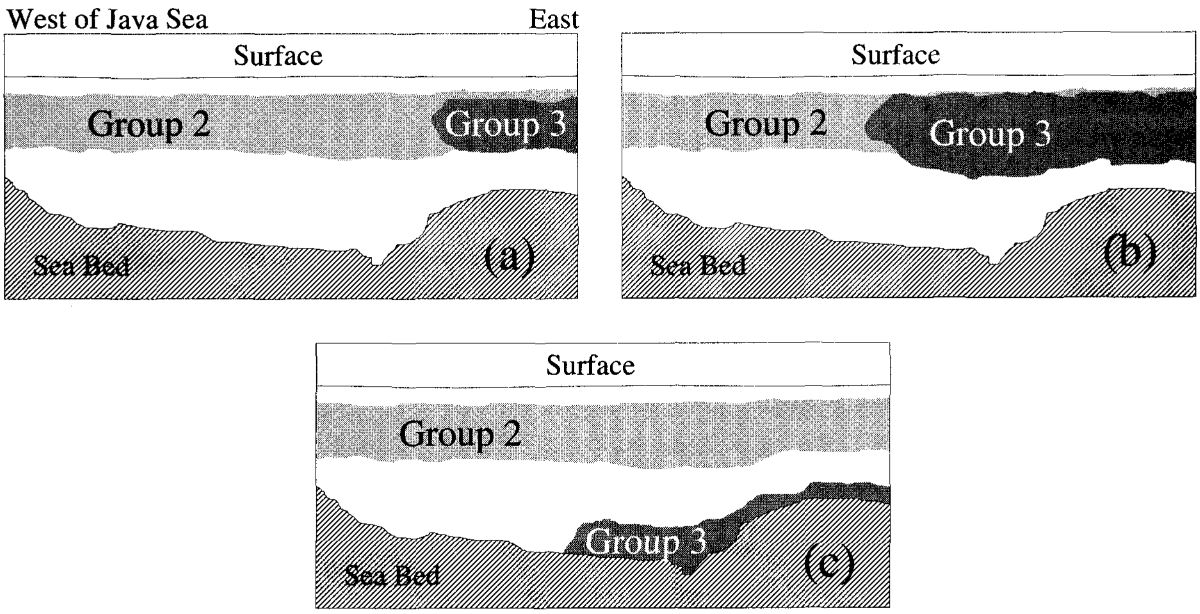


Figure 1 **Bathymetric distribution of the groups 2 and 3 according to a West to East direction in the Java Sea. (a) in February by night; (b) in October by night; (c) in October by day (from Petit *et al.,* 1995)**

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.

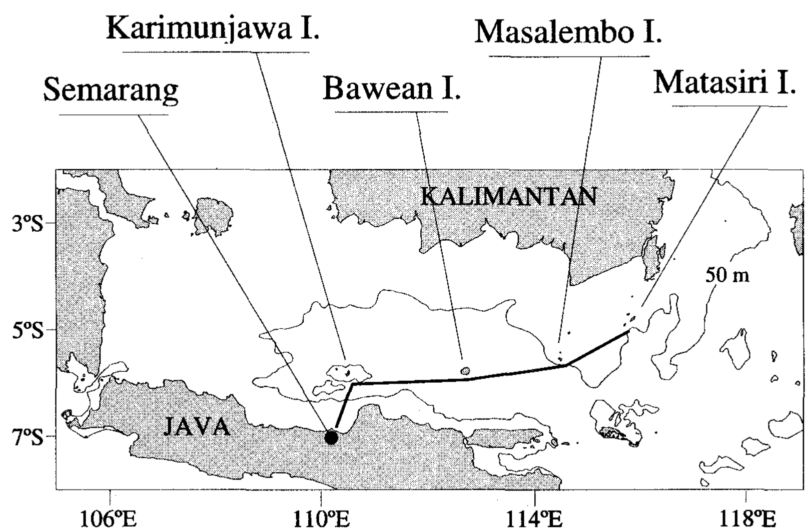


Figure 2 **Geographical location of the transect Semarang - Matasiri Island, with the position of the main islands encountered.**

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.

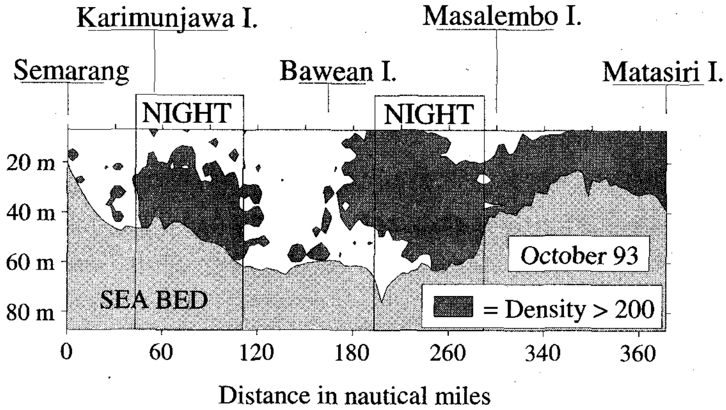


Figure 3 **Example of the representation of the density distribution in relative integration unit (r.i.u.) for a density threshold D=200. Case study : survey October 1993.**

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

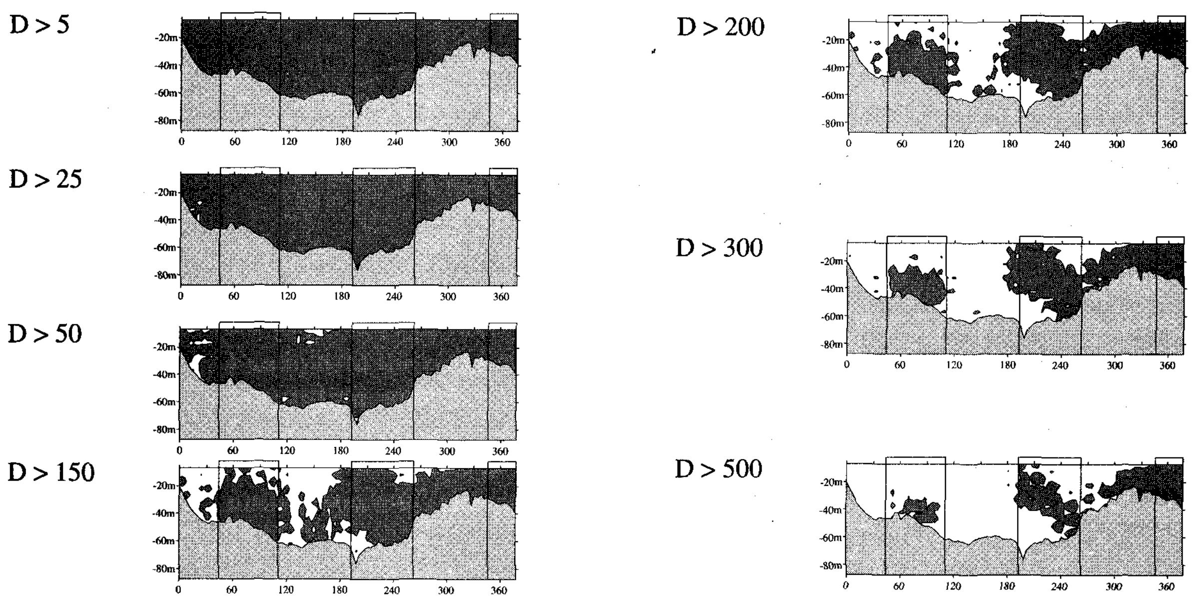


Figure 4 **Density distribution (r.i.u.) for the cruise Semarang - Matasiri Island.**

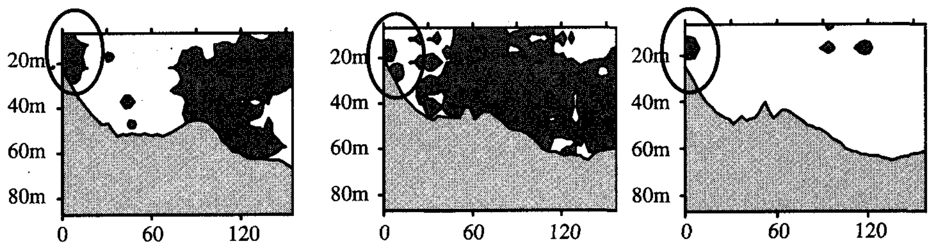
Gambar 4 **Distribusi densitas (r.i.u) dari pelayaran Semarang - Pulau Matasiri.**

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

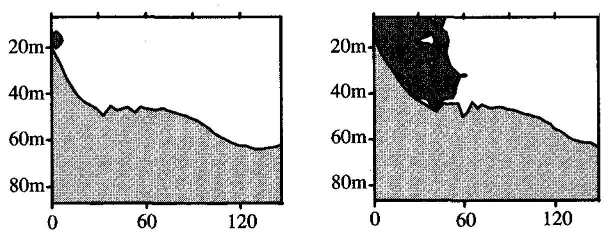
(b) Oct. 93 D > 100

(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

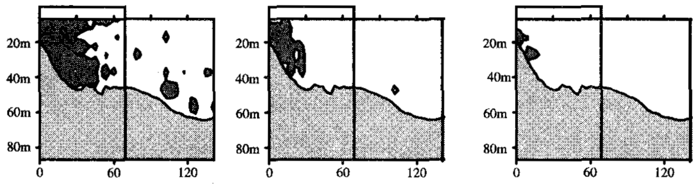
D >150



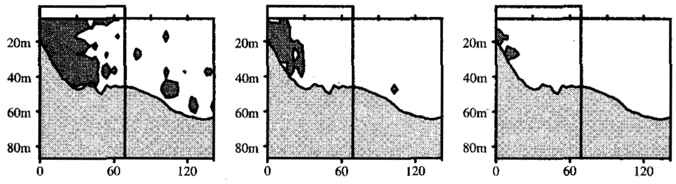
Data by : (a) Day (b) Night

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).

Dec. 92
D > 10

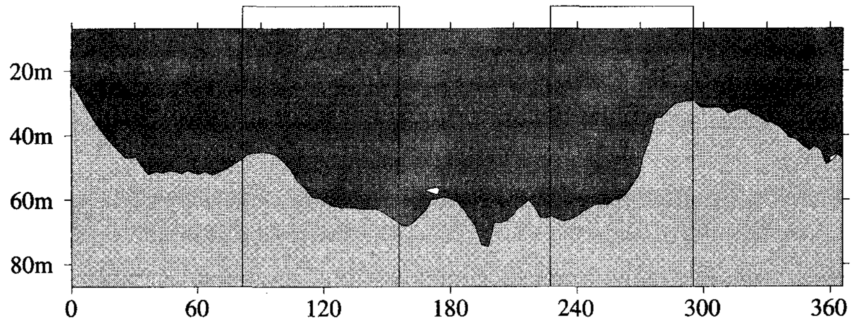


Figure 8 **Distribution of the densities above 10 r.i.u. between July and February.**
Gambar 8 **Distribusi densitas di atas 10 r.i.u antara bulan Juli dan Februari 1992.**

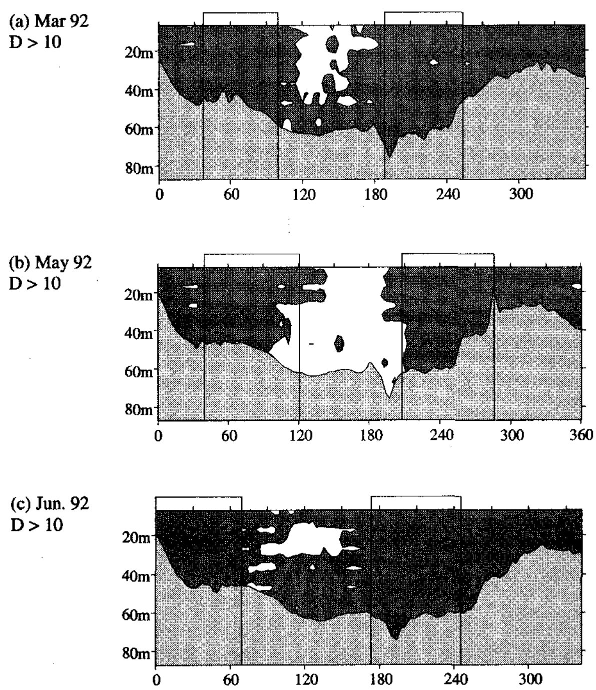


Figure 9 **Distribution of density, at least of 10 r.i.u., between March and June 1992.**
Gambar 9 **Distribusi densitas, paling tidak 10 r.i.u., antara Maret dan Juni 1992.**

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).

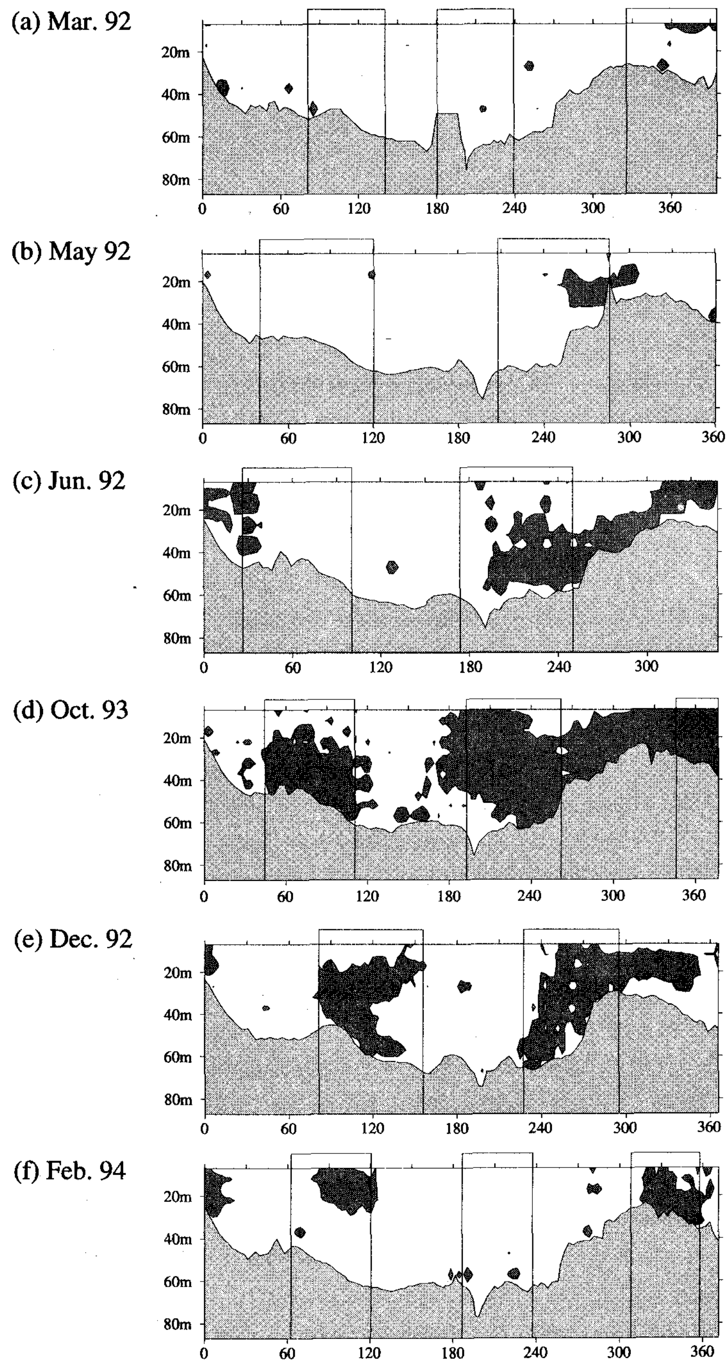


Figure 10 **Comparison of the distribution of the high densities (higher than 200 r.i.u.) during different periods of the year.**

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 :

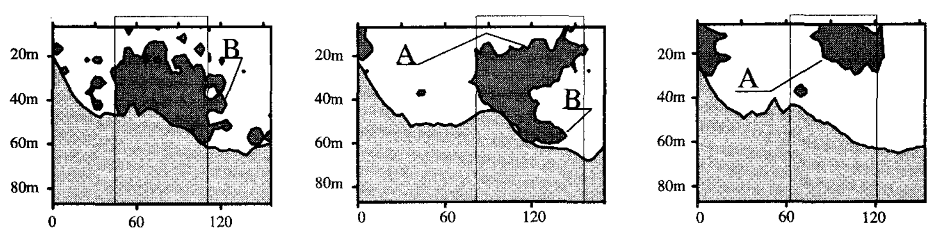
- during the day, observations show the presence of high densities in the shallow water area (Masalembo - Matasiri). These high day densities which could not be found in the area of deep water (Karimunjawa -- Bawean), characterize a subgroup living in the East area of the Java Sea up to Masalembo which 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.

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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.

PELAGIC FISH SHOALS IN THE JAVA SEA[1]

D. NUGROHO, D. PETIT, P. COTEL, N. LUONG

ABSTRACT

Two acoustical surveys took place in October 1993 and February 1994, covering the main part of the Java Sea, below 50 m depth. The echo-integration process was performed through a BioSonics 120 kHz Dual Beam echo-sounder. Fish shoal characteristics and their behavioural aspects were observed. The shoals' configurations were extracted from echograms and quantified. This information allows to represent the spatial and bathymetric distribution. An analysis on abundance and distribution of shoals is proposed, as well as their contribution to the global densities and a description of their behaviour during the day and night periods.
KEYWORDS : Java Sea, pelagic fishes, acoustics, shoals.

ABSTRAK

Dua survei akustik telah berlangsung dalam bulan Oktober 1993 dan Februari 1994, meliputi bagian utama dari Laut Jawa, dengan kedalaman dibawah 50m. Proses integrasi - gema dilakukan dengan echo-sounder BioSonics bim ganda 120 kHz. Karakteristik kawanan serta beberapa aspek perilaku ikan telah diamati. Konfigurasi kawanan ikan diekstrasi dari ekogram dan dikuantifikasikan. Informasi ini dapat menggambarkan pembagian menurut tempat dan kedalaman. Dilakukan suatu analisis terhadap kelimpahan dan distribusi kawanan ikan, selain kontribusinya terhadap densitas secara menyeluruh dan deskripsi perilaku mereka pada siang dan malam hari.
KATA KUNCI : Laut Jawa, ikan pelagis, akustik, kelompok ikan.

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

The continental shelf of the Java Sea is estimated at 442,000 km^2 (Durand and Petit, 1995) with an average depth of 40 m. The environmental conditions are controlled by a monsoon cycle. The total catch of pelagic fish by seiners was estimated at 485,000 tons in 1991, captured in an area representing 7% of the marine territory of Indonesia (Potier and Sadhotomo, 1995).

Previous studies on the state of exploitation by seiners since 1980, have related that the fishing operations take place with aggregation in areas depending on the season (Atmaja and Sadhotomo, 1985; Nurhakim *et al.,* 1987; Potier and Boely, 1990). To supply information on the importance of the stock and its availability, the estimation of density by acoustics is applied within the framework of the Java Sea Pelagic Fishery Assessment Project.

MATERIALS AND METHODS

The data analysis is based on two parallel acoustic surveys carried out in October 1993 and February 1994, during twelve days (Fig. 1). The data are collected aboard the stern trawler R/V Bawal Putih 1, with biological sampling obtained from pelagic and bottom trawls. The echo-integration was achieved by means of a Dual Beam 120 kHz echo-sounder connected to an interface INES MOVIES, for digitizing, display and integration of the signal.

The basic dimensions of the shoals (distance from the bottom, height and global relative reverberation) were extracted manually from echograms (which give the progress of integration for each ping and the total value by mile). Data postprocessing was performed throughout OEDIPE and SURFER softwares. As it is difficult to attribute a criterion of "pelagic" or "demersal" to the shoals close to the bottom, only the ones situated at more than 5 m from the bottom were taken into account in this study[2]. We selected also the shoals giving a reverberation level more than 50. As the monofrequency systems are unable to discriminate the species, these shoals can not be related to particular species. Nevertheless as Gerlotto (1993) points out, we may consider that aggregations are referred to species having momentarily the same "acoustical behaviour."

The environmental measurements are obtained by vertical profile measurements of temperature and salinity.

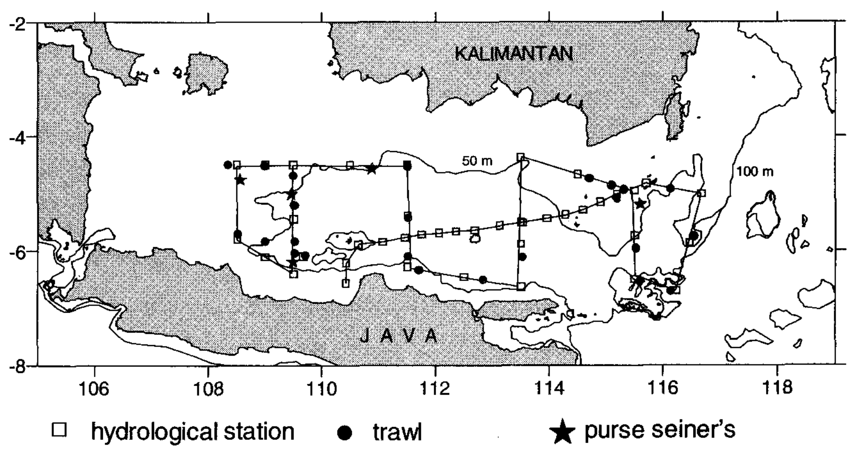


Figure 1 **Survey October, acoustic tracks, oceanographic stations and biological samplings.**

Gambar 1 **Survey bulan Oktober, jalur akustik, stasiun oseanografik dan sampel biologi.**

[2]The shoals, near the bottom, are scarce and uniformaly distributed.

Table 1 The general settings of the equipment.
Tabel 1 Susunan umum dari peralatan.

Frequency	: 120 kHz	Pulse duration	: 0.4 m sec
Power	: -3 dB	Ping rate	: 3/sec
Bandwidth	: 5 kHz	Depth range	: 125
TVG	: 20 log	Speed	: 6 knots
Angle trends	: 7° (narrow beam)		
	18° (wide beam)		

RESULTS

Hydrological conditions during the surveys

The mean saline conditions observed during the surveys are relative to the seasonal conditions and the topography. In October, winds and currents still bring up the oceanic influence throughout the continental shelf; the salinities are near 34‰. In February, winds and currents transport waters of low salinity (rains and outflows) from the western lands; the mean salinities fall to 32‰ (Durand and Petit, 1995; Petit *et al.,* 1995). The more interesting is the spatial location of the maxima between the two seasons : in October, we have a low gradient from West to East (max.); in February, the gradient tends to be opposite because of the bulk of salted water coming along the coast of Kalimantan where the depth is shallower. Consequently, the highest salinities, in February, are in the South West part of the Java Sea. This is well described in Figure 2, where the mean salinities appear more homogeneous in October than in February. In this latter, in the eastern part, the salinities grow only along the last transect. Between the two seasons, the mean temperatures vary only of about 1°C.

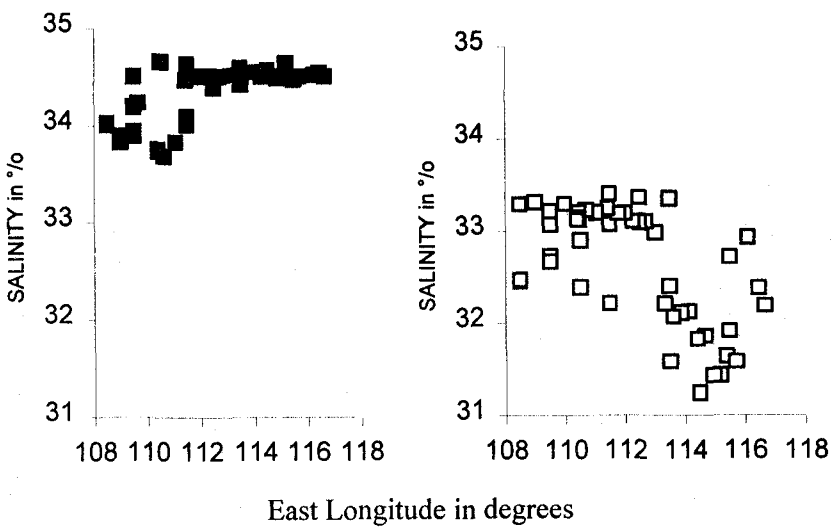


Figure 2 Longitudinal averaged salinity in October (left) and February (right).
Gambar 2 Rata-rata salinitas menurut letak lintang dalam bulan Oktober (kiri) dan Februari (kanan).

Abundance and spatial location of shoals

The total number of shoals recorded in October is 197 and 110 in February. Most of shoal reverberations are low in both seasons. In October, the shoals are distributed almost over the whole area, but the maximum is concentrated in the eastern part around the Matisiri and Kangean Islands (Fig. 3). This abundance tends to decrease through the West, except in the coastal zone of Java.

In February, the bulk of shoals is concentrated along a curve from the North of Kangean Islands, the continental slope and continuing in the shallow waters, North of Masalembo Islands. In the western part, numerous shoals are remaining in the North of the Java Coast.

Between the two situations, the more emerging event is the disappearance of shoals in the middle and south eastern part of the Java Sea. The mean number of shoals per mile within nine longitudinal strata is relatively low in both seasons (0.047 to 0.325 in October; 0.014 to 0.186 in February, Fig. 4).

The spatial distribution of reverberation levels.

Between February and October, the mean reverberation levels of shoals are the same : 199.4 (October) and 199.8 (February). Taking into account the longitudinal distribution of the number of shoals (Fig. 4), we split the area in two strata; West and East of 112°E. The histogram of relative reverberation (Fig. 5) shows that a common mode (< 200) appears all over the area. The modes 200-500 stay numerous during the South-East monsoon, in the eastern part; the last mode (> 1000) is only in the East.

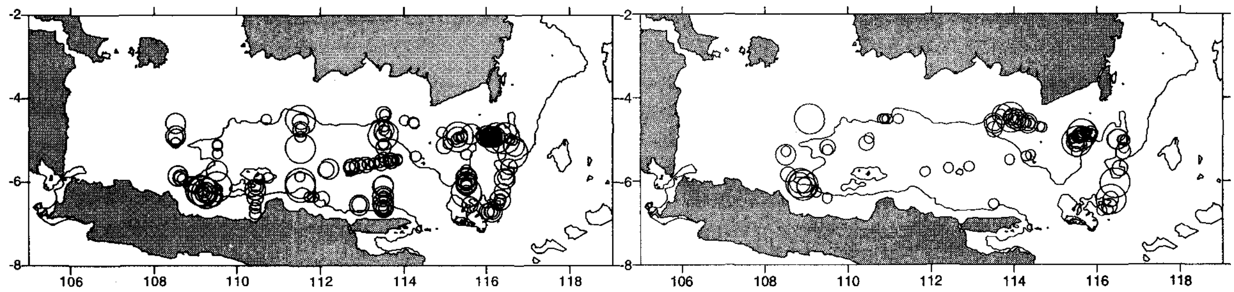


Figure 3 Geographical distribution of pelagic shoal density in October (left) and February (right).

Gambar 3 Distribusi geografis dari densitas kawanan ikan pelagis dalam bulan Oktober (kiri) dan Februari (kanan).

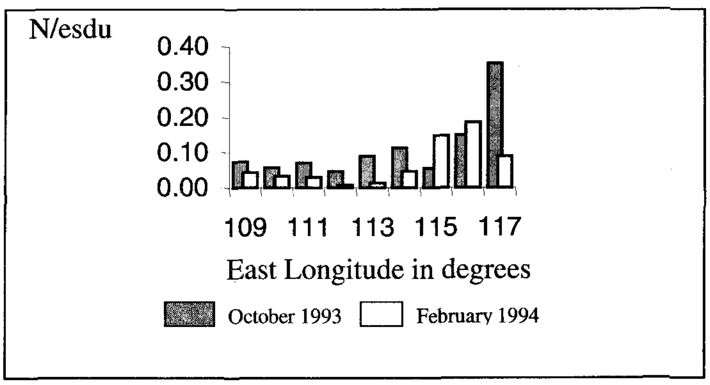


Figure 4 Longitudinal distribution of averaged number of shoals per ESDU (nmi).

Gambar 4 Distribusi rata-rata jumlah kelompok ikan per ESDU (mil laut) menurut letak garis lintang.

Thus, until now, the study of reverberation levels gives limited information. The mean levels are comparable between the two seasons; the shoals are low reverberating, more numerous in the East during October and February, and almost 40% of the present density have disappeared.

Vertical distribution and day-night variation

The vertical distribution revealed that the shoals are more dispersed during the South-East monsoon : the occupation of the space is better (Fig. 6). The modal vertical location is not the same between the two seasons, *i.e.*, 40 m in October, 20 m in February. The global behaviour changes also : the shoals tend to stay during the night in October, and the mode is going down during day. In February, there is no particular change in location between day and night.

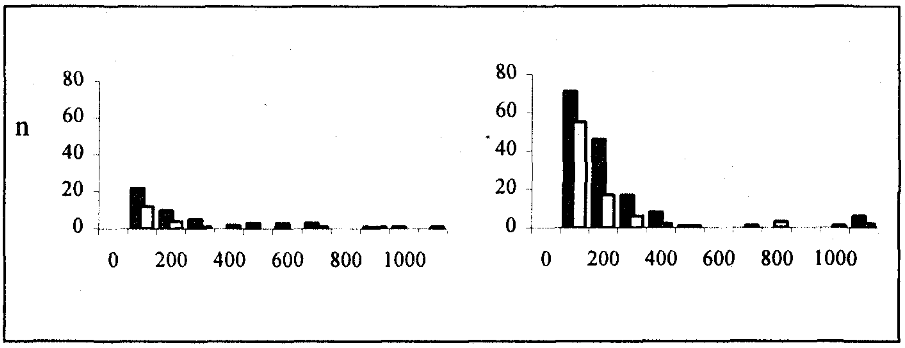


Figure 5 **Frequency histograms of shoal density on both areas (left, West of Long. 112°E, right, East of Long. 112°E).**

Gambar 5 **Histogram frekuensi densitas kawanan ikan di kedua area (sebelah kiri : area barat bujur 112 T, dan sebelah kanan : area timur bujur 112 T).**

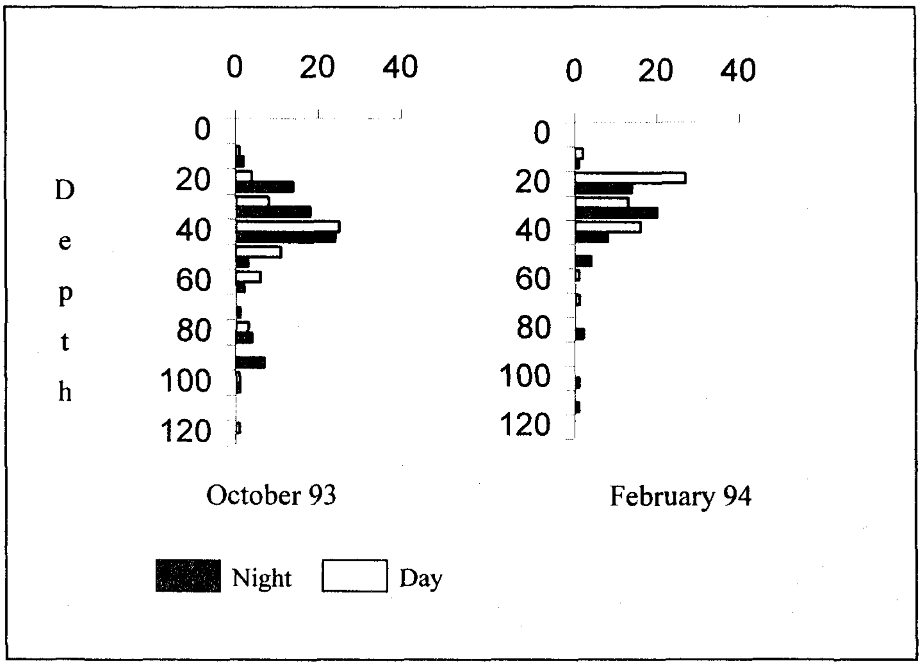


Figure 6 **The number of shoals vs depth.**

Gambar 6 **Jumlah kawanan ikan menurut kedalaman.**

The more interesting information seems to be that the number of shoals is more important during the night in October, although the pelagic populations are usually scattered by night (Tab. 2). An evaluation on the mean levels of reverberation shows that the highest reverberation levels appear by day in October when the small ones are found by day and night. In average the situation is inverted : the mean level is highest in February; the phenomenon could be in relation with the lunar cycle (February : full moon; October : new moon).

Table 2 Density of shoals by day and by night.
Tabel 2 Densitas kawanan siang dan malam.

	October 93		February 94	
	day	night	day	night
N	76	121	72	38
Minimum	50	50	50	50
Maximum	2474	1527	1151	3177
Mean	262	160	172	253
Variance	162620	41164	51857	300307

DISCUSSION

On this study, various results have been extracted :

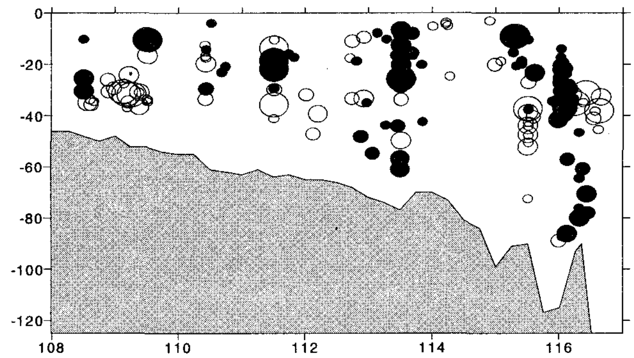
- proportion, relatively low, of pelagic (or semi pelagic) stock able to aggregate,
- identity of the reverberation mean level of shoals between the seasons,
- big relative abundance of small shoals everywhere in dry season and more located in wet season,
- occurrence of bigger shoals in depth and in the eastern part in October,
- permanence of shoals in the extreme west part, particularly near the Java Coast,
- difference of behaviour for the global population between the two seasons.

Studies on abundance and distribution of fish through acoustics have been done in the past around Kangean Islands (Barus and Rumeli, 1982) and in the middle part of the Java Sea (Boely and Linting, 1986; Boely *et al.,* 1991). During this latter cruise, the same dispersed small shoals have been discovered. But these surveys were very limited. Since the end of 1970, investigations have pointed out high rates of pelagic fish exploitation in the middle of Java Sea (Sudjastani, 1978). After 1980, an active development of new fishing tactics has been followed by the increase of the total catch (Sadhotomo and Widodo, 1992; Potier and Petit, 1995).

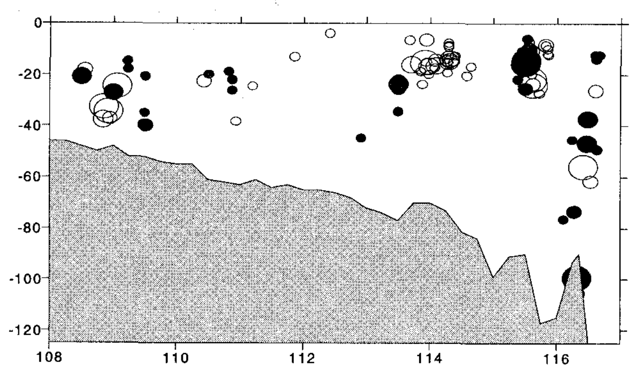
Recent investigations suggest the presence of 3 groups of fish inhabiting the waters of the Java Sea (Petit *et al.,* 1995) : a coastal one, living close to the Java Coast; a neritic one covering the whole of the continental shelf, and an oceanic one that might have semi demersal behaviour. Even though analogy cannot be made totally between global data of density and shoals, we have to consider that the small shoals participate to the group 2, as the bigger from the eastern part could participate to the group 3.

Acoustic evaluation reveals that the mean density drop is 58% by night and 48% by day between October and February. For the aggregated part, the decreasing is 49% and 38%. The migrating populations do not belong exclusively to the shoals; or from an other point of view, an important part of the "pelagic" population does not aggregate. Even though the fleets of big seiners are not operating on shoals with their new tactic (light attraction), the behaviour of the part of pelagic fish staying aggregated by night in October, could encourage attraction and aggregation.

In February, the percentage of total catch in central Java Sea represents only 9%; then, the most part of big seiners operates in the Makassar Strait (Potier and Sadhotomo, 1995). This seems related to the disappearing of the big densities in the eastern part. But, as revealed by the apparent change of behaviour, the catch ability could be less favourable : deleted waters in wet season may be more turbid and this may disturb the light attraction. Potier and Boely (1990) and Boely *et al.,* (1991) suggest that the seasonal changes of fishing grounds could be related to the ones of environmental conditions, particularly the salinity. Obviously, the disappearance of shoals in the eastern part (Fig. 7) seems to coincide with the low salinity (less than 33‰, Fig. 2).



October



February

Figure 7 Longitudinal day (white) and night (black) variability of shoals density (depth in metre).

Gambar 7 Keragaman densitas kawanan menurut bujur pada siang (putih) dan malam hari (hitam) (kedalaman dalam m).

Five exploited species live in the Java Sea. *Decapterus macrosoma* represents the bulk of the catch during the dry season in the eastern part. It is sure that this species is migrating out of the continental shelf in wet season. But, does this species participate or not to the shoals? What are the ecological affinities of the other species? (*D. russelli, Selar crumenophtalmus, Rastrelliger kanagurta, Ambligaster sirm* and *Sardinella gibbosa).* In wet season, we met the "highest" salinities in the south western part of the Java Sea; we met also in the same area, relative big densities and shoals. But another group of shoals appears in shallow water, South Kalimantan (29 < S‰ < 31‰). Experimental samplings and further investigations will be necessary for satisfactory interpretation.

ACKNOWLEDGEMENT

We would like to thank Dr. J.R. Durand, Dr. J. Widodo, Dr. F. Gerlotto and Dr. M. Fatuchri Soekardi for their kindly helpful comments and improved English. And to all the skipper of R/V Bawal Putih we also thanks to their collaboration during the cruises.

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DISCUSSION

(Chairman Dr. PASARIBU)

Dr.NURZALI

Q : - Why do fish schools disappear between October and February, which are both in the same season ?

A : - Maybe, during 1993, the dry season was longer than before; thus, October is still representative of the South East monsoon. If you look at the salinity, the high one is present during the South East monsoon in the Java Sea and not in the West monsoon. Consequently, February and October have not the same conditions. The phenomenon is different : in February, the schools are less in number and stay close to the surface; in October, greater number of fish schools, higher density. Between both seasons, in the eastern part, there are still some schools, but in the western part, they have disappeared. Maybe, they are composed of different species. Here are still preliminary results from sampling quite few data from purse seine, collected during our acoustic surveys. If you compare the area North of Tegal, Kariwono, at about 108 ° East longitude, according to the time, and the ones where species belong, you can see that *Macrosoma* has disappeared in the western part of Bawean. But, to discriminate between February and October, we have to look at more carefully. I have not answered your question, but there are some data which can define that difference. If you ask me where are the schools in February, it is quite tough to work with. It is still at the beginning and if we have some other project, maybe we could get more details such as these ones.

Q : - Based on your own experience, which are the species the most dominant ? What accuracy do you estimate about schooling size, their weighting, etc. ? Personally, I did it on demersal species, on prawns and shrimps in the Java Sea and I predicted that, from a first estimate of 200 kg, our error was 5 to 10 kg; that is to say : my confidence on the estimate was 25%. What is your estimated percentage ?

A : - Actually, it is very difficult to say. One of the reasons is that it is the first time I work with an acoustic team and I discovered that there are a lot of variables to correct in the same time. If you did your estimation by guessing like in the old fashioned ways before 1990, it is not the case nowadays and we must be careful about these predictions. Mr. Gerlotto will give you some more explanations on school estimate. I assume, here, that the school is a cylinder; in fact, it is still questionable about this cylinder. But, it remains the easiest way to express what a school is, and, from echograms, to use the Johannesson's formula. If you ask me : how many tons ? Maybe, we can combine average size of school fish sampled and the Target Strength values from Dr. Cotel's results.

About the dominant species, the areas have already data on species. The aggregated fishes data, shown before, were collected from light fishing. If we work on natural schools, we will have differences. Are the schools below the purse seiners the same as the ones below the transducer ? We have some data from the sampling but, mainly from the Target Strength measurements.

Mr. NAHMULIN

Q : - How many variables did you use to support your conclusion ?

A : - I only used the salinity and temperature parameters. But I did not correlate them in a statistical approach with the school parameters, until now. It was just done to show the difference between both seasons, October and February, characterized by a difference in salinity and temperature. I have not yet worked on the relation between schools and these variations of environment.

Q : - Have you observed any difference along these 5 years ? You, also, do not mention anything about the currents whose acting is very important.

A : - Personally, I only used temperature and salinity, in my study. There are maybe data about the currents in the Project archives.

Dr. MERTA

Q : - Are there any differences in school size between East monsoon and West monsoon ?

A : - If you look at the estimated diameters between both seasons, on the first figure, you can see that in the south-east monsoon, the presence of schools of broader scales, with large and small diameters. The small diameter ones occur in both seasons. If the Johannesson's formula is valid, there is a difference in diameters. If we look at the echograms, about their behaviour, it is still confusing. Are they more scattered, small but many ? Or, do they stay more compact ?

By playing back echo-integration files, using the Movies B software from IFREMER, we could define more precisely the shape, the size and the parameters of the schools through different threshold settings.

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.

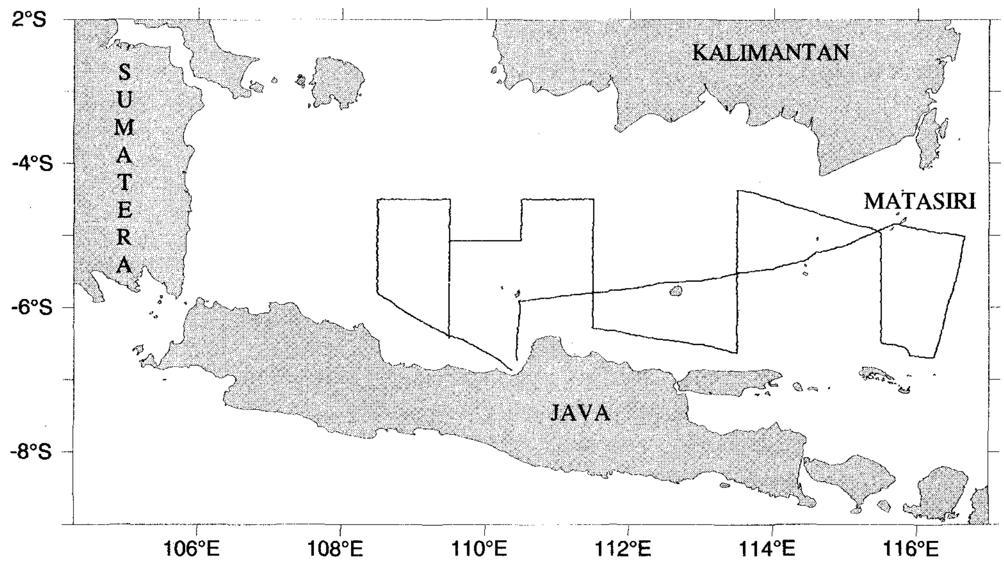

Figure 1 October 1993 and February 1994 : echointegration surveys in Java Sea.
Gambar 1 Oktober 1993 dan Februari 1994 : survei ekointegrasi di Laut Jawa.

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.

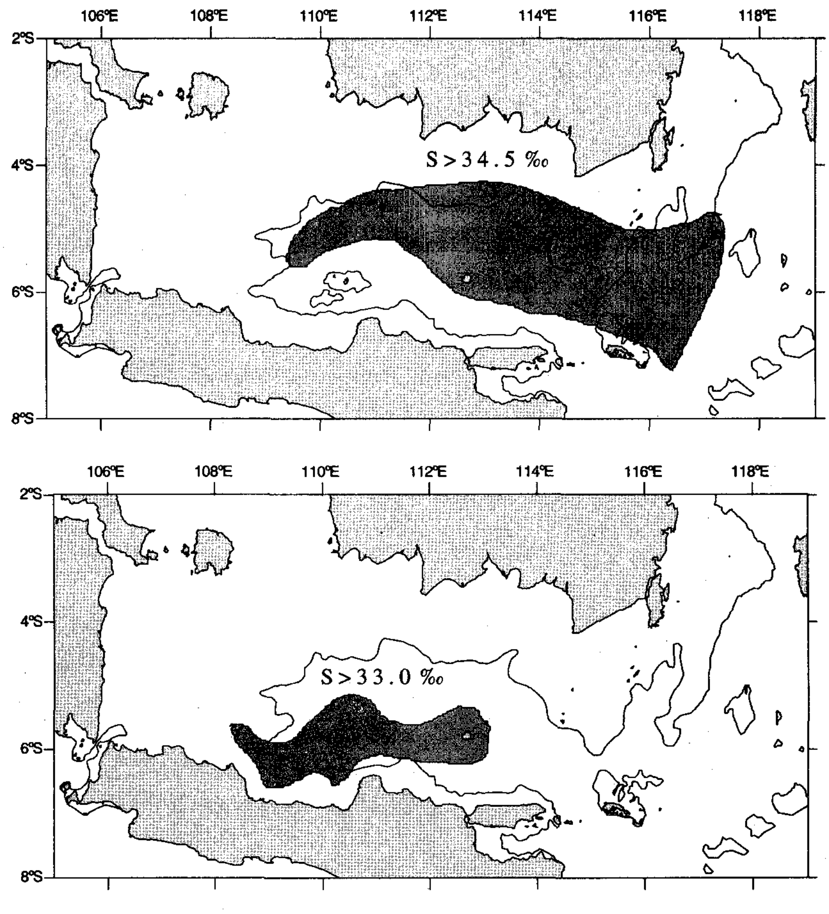

Figure 2 **Location of the mean salinity maxima in October 1993 (up) and February 1994 (down).**

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.

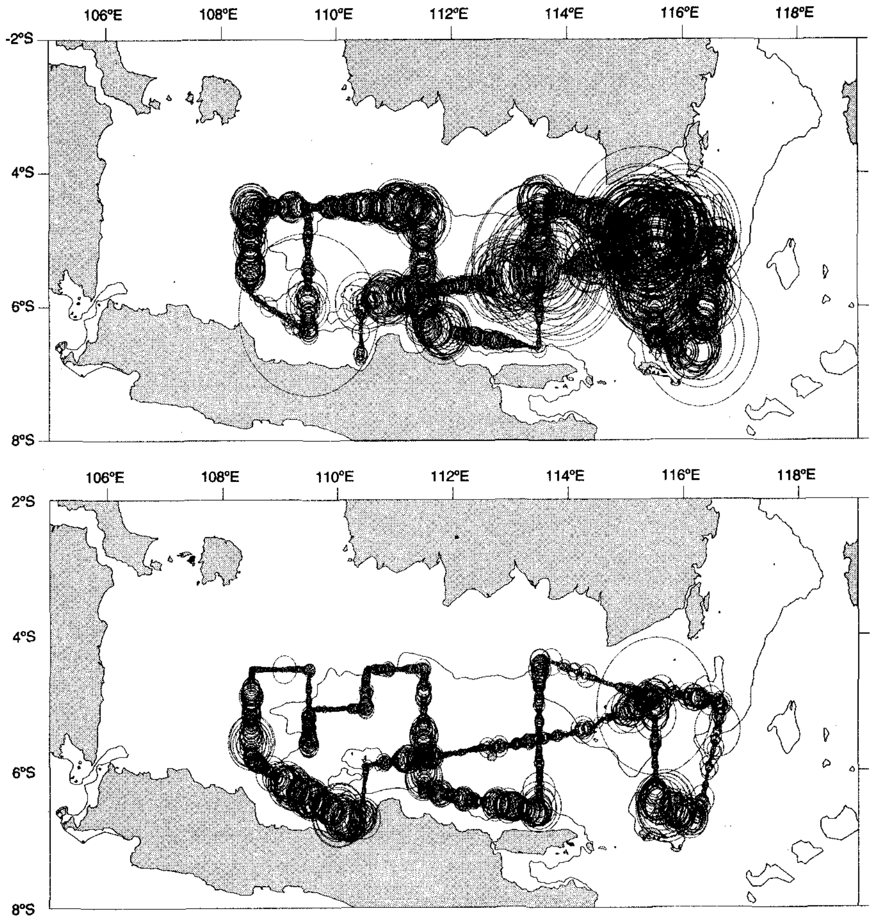

Figure 3 **Relative density of pelagic fish in October (up) and February (down).**
Gambar 3 **Densitas relatif ikan pelagis bulan Oktober (atas) dan Februari (bawah).**

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).

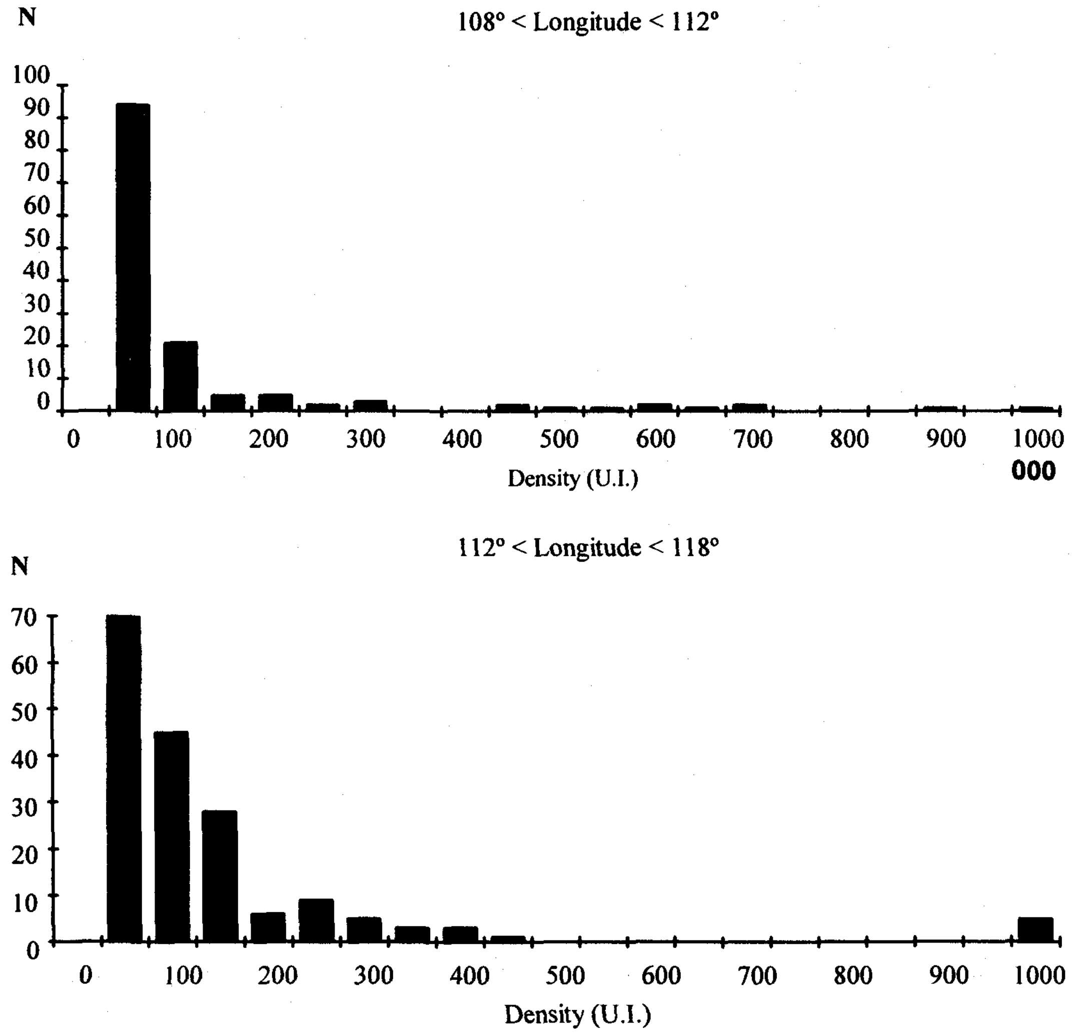

Figure 4 **Distribution on both sides of the longitude 112°E of the number (N) of fish schools according to density in October 1993 (survey 34).**

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.

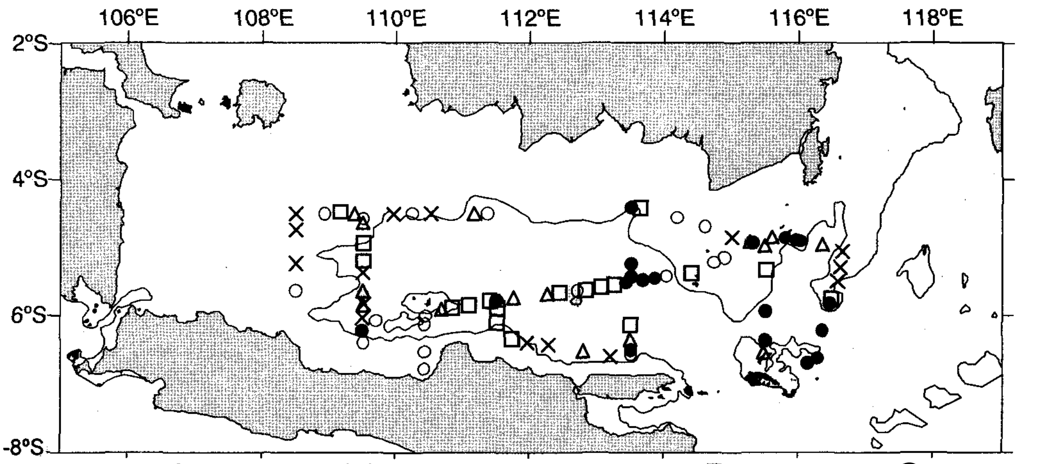

Figure 5 Distribution of the mean TS values (in dB) in October 1993.
Gambar 5 Penyebaran rata-rata nilai TS (dalam dB) dalam bulan Oktober 1993.

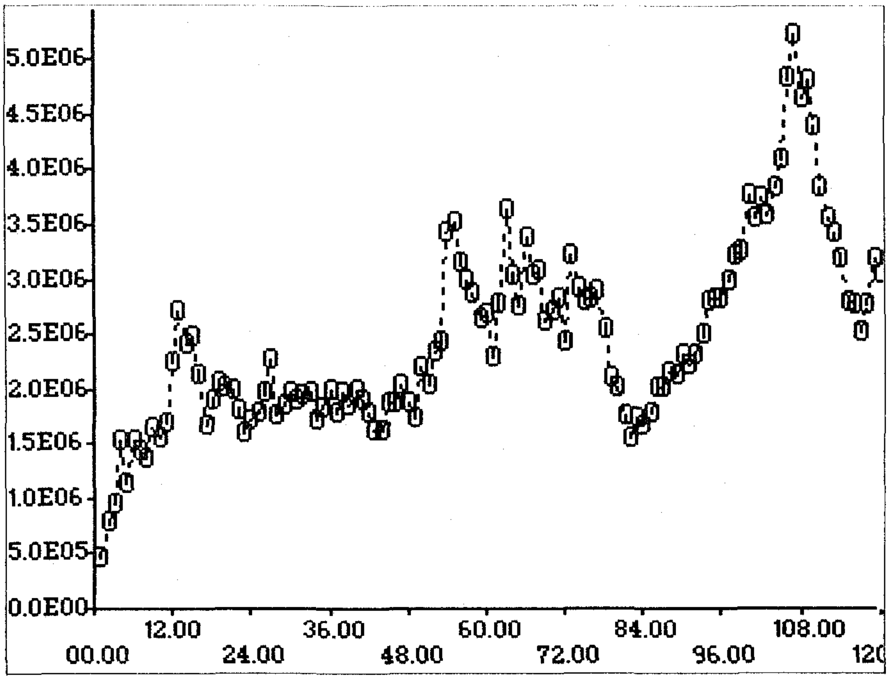

Figure Variogram on the night densities in October 1993.
Gambar 6 Variogram densitas malam hari dalam bulan Oktober 1993.

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.

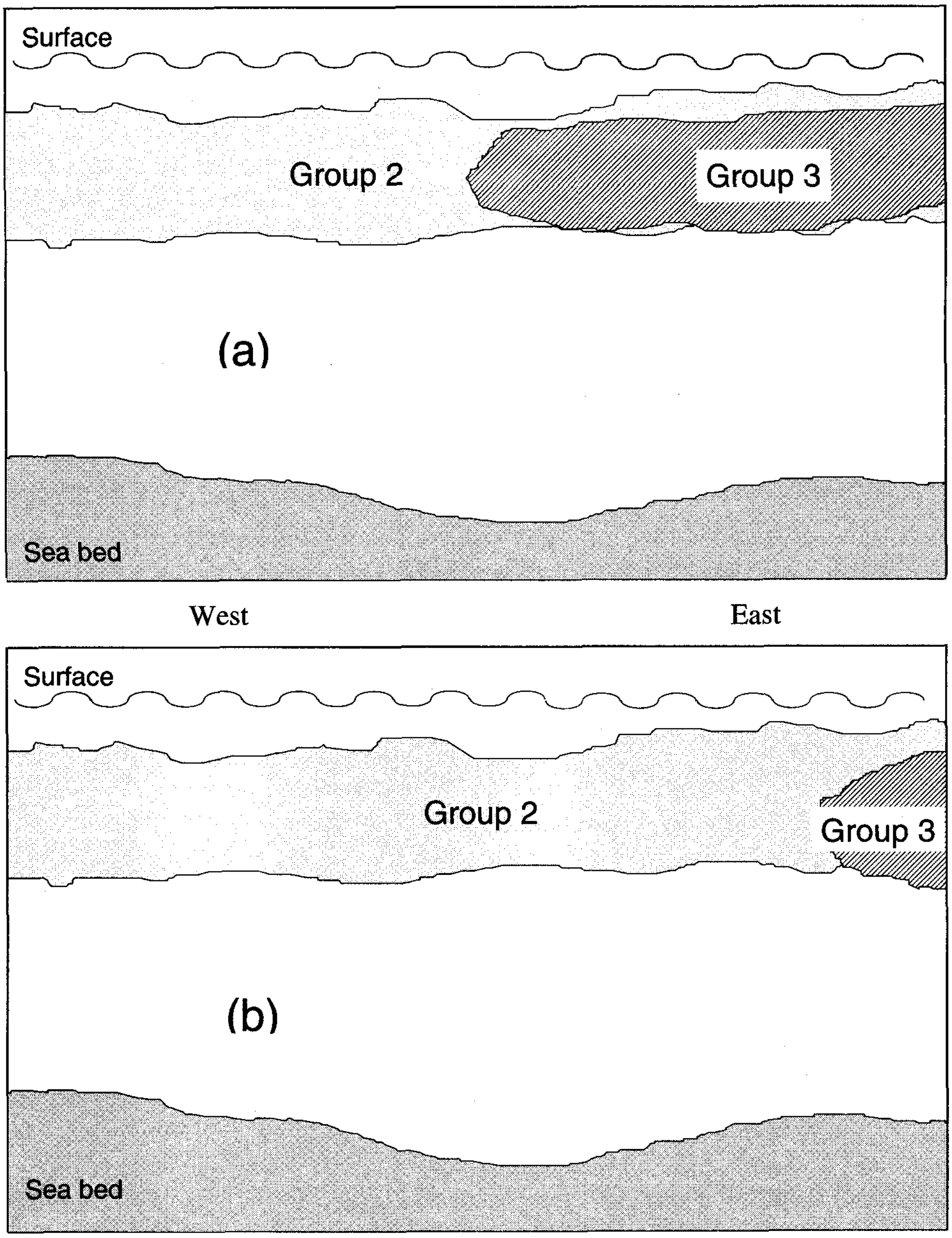

Figure 7 Group 2 and 3, night annual distribution of pelagic fish from West to East of the Java Sea : (a) October, (b) February.

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

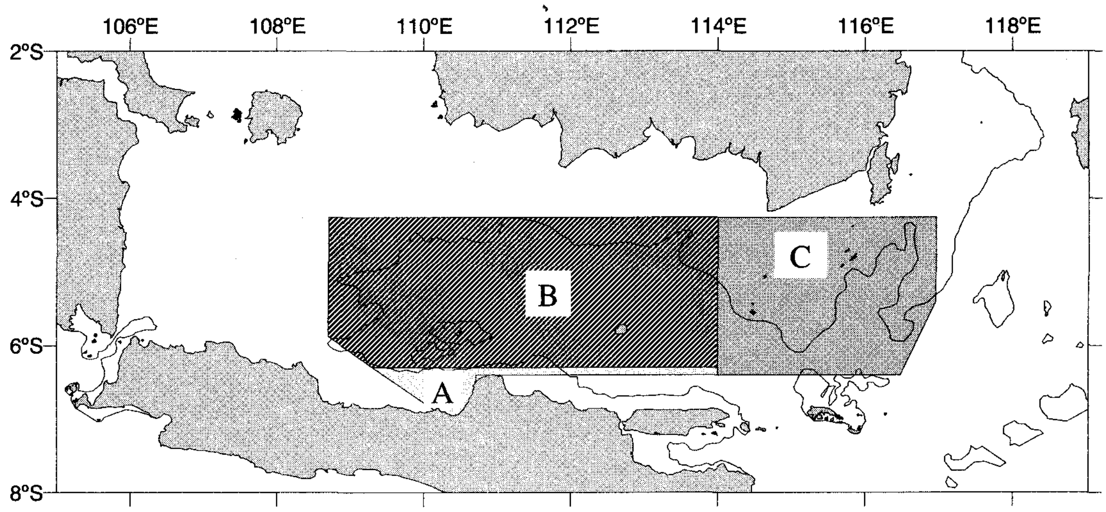

Figure 8 **The 3 strata of the Java Sea, following the location of the main fish populations.**

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.

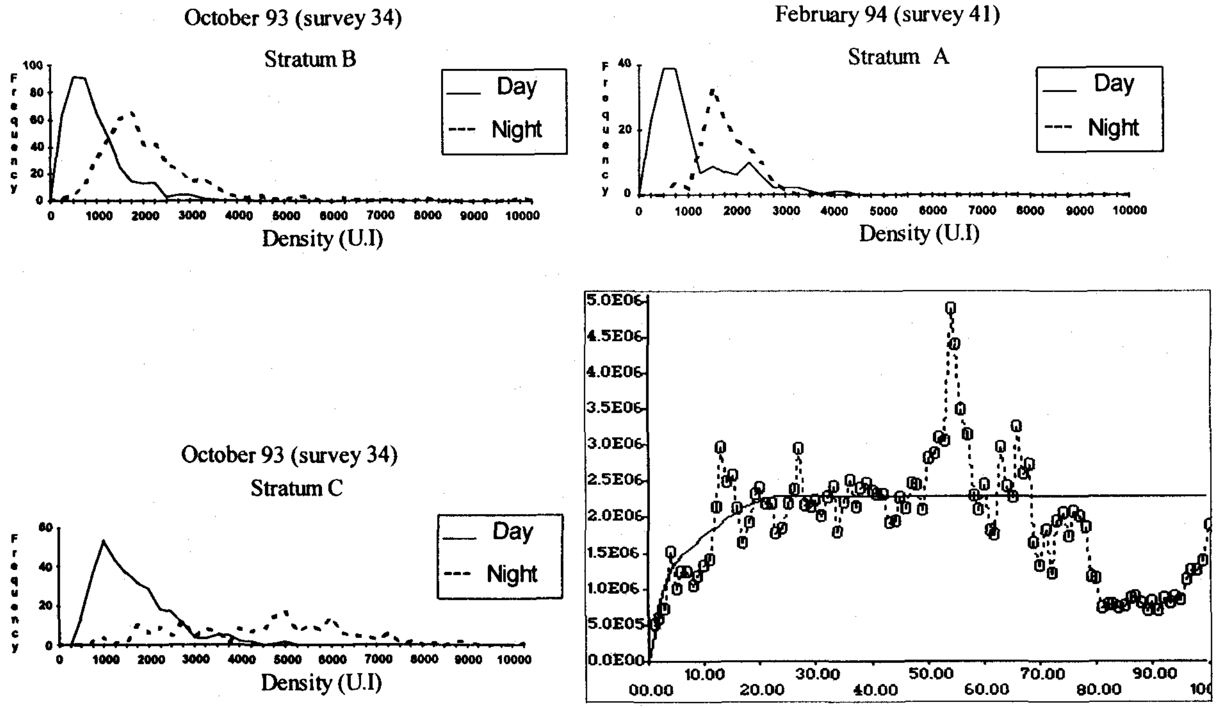

Figure 9 **After stratification, frequency distribution of densities into the 3 strata and one aspect of variograms (here, for the stratum B, night densities, in October).**

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.

DENSITIES AND BEHAVIOUR OF PELAGIC FISH POPULATION ALONG THE JAVA AND SUMATRA COASTSIN WET SEASON

D. PETIT, P. COTEL, D. NUGROHO

ABSTRACT

The coastal borders of northern Java and eastern Sumatra have been prospected during the acoustic surveys, in the depth of about 15 to 50 m, in wet season. The measures of relative density per nautical mile, the vertical distribution of the abundance and shoals have been analyzed. The general characters can be drawn : they are the extension of an abundant semipelagic fauna occupying the bathymetric strata from 25 to 45 m, and the existence of a dominant pelagic fauna, more coastal. Shoals, low reverberating, are present in all areas but are dominant in the coastal border; the more reverberating aggregations are more off shore. From the East to the West, their bathymetric localization increases in the sectors near oceanic influences, they are more dense and near the surface. From East to West, the abundance of schools and total density decrease. This fact seemingly has to do with the extension of the relatively shallow zones. Two sectors show a particularity : the Bay of Semarang with densities sometimes big, which could be related to the seasonal topography, and the surroundings of the Sunda Strait, zone of passage and exchange for the deep pelagic population.

Those observations globally confirm the stratification tentative which had been carried out during the Workshop of 1994, in specifying the geographical extension of the coastal stratum, very narrow in front of Java, and in proposing that one part of the semipelagic population which constitutes the wealth of the East of Java Sea in dry season, should migrate in wet season towards the slopes of the coastal border.

KEYWORDS : Java Sea, Sumatra, acoustics, pelagic fish, abundance, aggregation, distribution, zonation.

ABSTRAK

Keberadaan ikan pelagis di perairan pantai utara Jawa dan pantai timur Sumatra pada musim Barat telah diamati melalui survey akustik pada kedalaman antara 15 hingga 50 meter. Pengamatan kepadatan relatif per mil, penyebaran tegak kelimpahan serta keberadaan kelompok ikan dibahas dalam tulisan ini. Hasil pergamatan tersebut memperlihatkan karakteristik bahwa dominasi kelimpahan fauna semipelagis dan pelagis berada pada lapisan kedalaman 25 hingga 45 meter. Pengelompokan ikan pelagis semakin berkurang pada perairan lepas pantai. Penyebaran kedalaman secara membujur ke arah barat semakin dangkal dan dipengaruhi oleh lingkungan oceanik, sedangkan besarnya kepadatan semakin tinggi pada lapisan permukaan. Demikian pula keberadaan dan kelimpahan kelompok ikan serta total kepadatan cenderung berkurang dimana diduga berhubungan dengan semakin dangkalnya kedalaman perairan. Selain itu, dua hal spesifik dapat ditunjukkan berdasarkan hasil penelitian ini yaitu : pertama, kepadatan di perairan sekitar Semarang terkadang tinggi karena adanya pengaruh musim; dan kedua, perairan sekitar Selat Sunda merupakan perairan lintasan ruaya ikan pelagis laut dalam.

Secara umum, pengamatan tersebut memberikan informasi bahwa uji stratifikasi yang telah dilaksanakan pada pertemuan ilmiah pada bulan Desember 1994, khususnya pada stratifikasi kelompok ikan secara geografis, keberadaan ikan pelagis di perairan pantai utara Jawa sangatlah sempit dimana sebagian kelompok populasi ikan semipelagis pada musim timur yang berada di bagian timur laut Jawa bermigrasi kearah pantai pada saat musim barat.

KATA KUNCI : Laut Jawa, Sumatra, akustik, ikan pelagis, kelimpahan, agregasi, penyebaran, zonasi.

Until 1995, the acoustic surveys PELFISH had principally concerned the central zone and the East of Java Sea, which constitutes the zones of seasonal activities of big seiners (Potier and Sadhotomo, 1995). A test of stratification of pelagic population has been realized during the Workshop AKUSTIKAN I, December 1994. It was based on the acoustic data collected during the 2 surveys (October 1993 and February 1994) covering the Java Sea (Petit *et al.,* 1995). The study came to the conclusion that there were 3 strata of population : oceanic, neritic and coastal. The extension and characteristics of the last stratum however remained inaccurate, due to the lack of sufficient sampling.

From April 1994 to May 1995, three surveys have been done along the coastal zone of North of Java and a part of East of Sumatra, in wet season. The following results concern the relative variations of total density as well as variations of behaviour as they appear within the data collected during the nycthemeral cycle.

The sampling has been realized on board of R/V Bawal Putih I, a stern trawler, with a Dual-Beam echo-sounder of 120 kHz frequency and postprocessed with different software described elsewhere (Petit *et al.,* 1997). The integration of echoes per mile has been realized at the speed of about 6 knots, with 10 m interval from the surface to the bottom. The measures of abundance represent the densities by surface and are described in relative units. The vertical localization and the reverberated energy of the schools, always in relative units, have been extracted by observation of echograms. The play back of some transects in laboratory with a higher threshold (42 mV) than the one adjusted during the surveys (33 mV) enables to evaluate the proportion of targets more reverberating. In February and May 1995, the salinity has been measured at fixed station by vertical profiler. During the prospecting, some measures of TS have been performed, but this will not be much elaborated.

MATERIAL AND METHODS

The tracks of these 3 surveys are represented in Figure 1. They were carried out in April 1994 for the sector north of Sumatra, in February 1995 for the eastern part of Java, in May 1995 in the western part of Java and southern side of Sumatra. On this figure are also overlaid the southern transects carried out during the survey of February 1994 which covered the whole Java Sea.

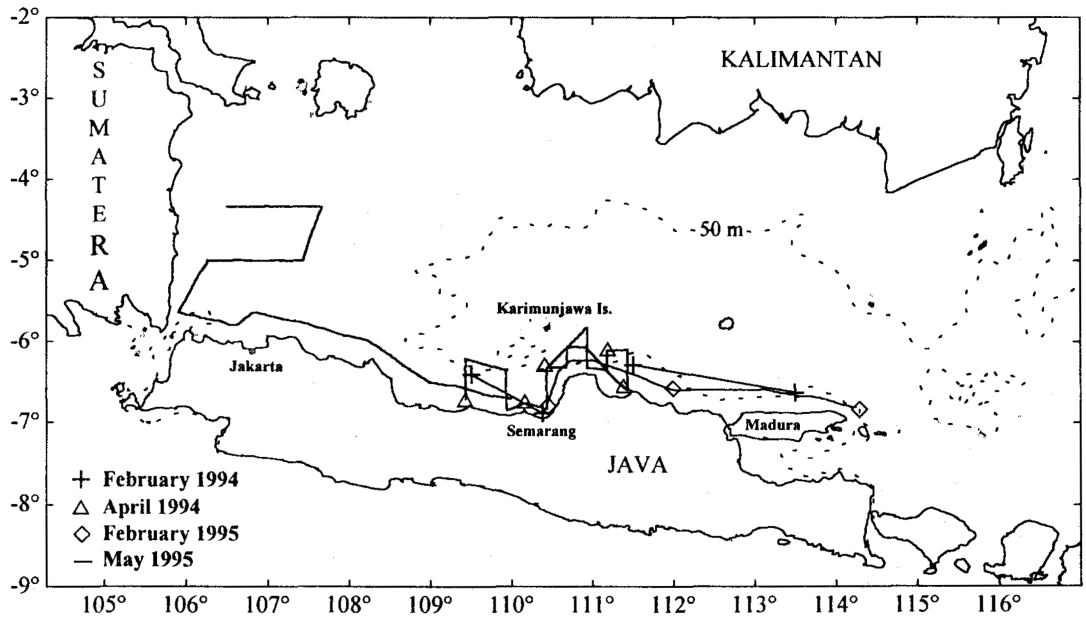

Figure 1 **Location of surveys along the Java coast in February, April and May.**
Gambar 1 **Daerah dan lintasan survey sepanjang Jawa, Februari, April dan Mei.**

Unfortunately, lacking for information on the accurate nature of detected targets -- the rare trawls realized (5 fishing operations upon which 3 pelagic trawling in April, 3 bottom trawls in May) -- practically did not report on the pelagic fauna. However, the inquiries carried out by biologists of the Project at the ports of unloading have given a very accurate information on the composition and proportion in species, at least those concerning the commercial targets in the fishing zones, that is all the north coast of Java, but not Sumatra. It concerns essentially the sardines (among which *Sardinella gibbosa* and *Dussumieria acuta*), the scads (*Decapterus russelli*, *Selar crumenophthalmus*) and the mackerel (*Rastrelliger spp.*) (Hariati *et al.*, 1995; Potier and Sadhotomo, 1995).

RESULTS

Haline situation

Following the whole surveys realized by the Project, a synthesis of the haline seasonal evolution has been described (Petit and Cotel, in this book).

In February, the maximum phase of desalinization in the Java Sea begins. The action is marked in the northern part with precipitation on Sumatra and Kalimantan. The Java coast begins to be influenced by local precipitation and the important desalinization remains coastal (delay of flow). During the survey of February 1995, the water is between 32.5 and 33‰, with persistence of vertical gradient in the extreme East (oceanic influence in depth) whereas near by the coast, in front of Semarang, the desalinization is well-moved forward (water lower than 33‰). Off shore, in front of Semarang, there is a zone of water higher than 33‰, phenomenon which has already been observed in February 1994.

In May, the survey has taken place in the period of inter-season along the west coast of Java and East of Sumatra. The desalinization, by vertical mixing reaches its maximum effect with disappearance of gradient. On the transects where the depth is lower than 40 meters, the salinity is practically constant from the surface to the bottom, 32.5‰ in average; the salinity is little higher in the South of Belitung Island. Between February and May, the whole of vertical and horizontal gradients have disappeared, that leads, then, to a maximal standardization of the salinity in the Java Sea, towards the lowest one. During the survey of April 1994, in front of Semarang, no observation has been collected.

Survey of February 1995

Four transects at 10-20 miles from the coast are represented, beginning from the East of Madura Island till Semarang. The mean depth decreases from 47 m in the East until less than 30 m along the Java coast.

The variations of abundance (vertical density per mile, Fig. 2) indicate the presence of 3 zones from East to West. Far out from the Java coast, in deeper zones, the densities are the weakest, in particular at the longitude of Surabaya; these densities increase along the coast towards to West (bottom lower than 30 m) and the maximum is found near the Bay of Semarang. The playback of echo-integration data with higher threshold than during prospecting (42 mV instead of 33 mV) shows that the enrichment towards the West is also qualitative : the proportion of more reflecting targets, 18% in the East, exceeds 24% along the Java coast and attains 30% in the Bay of Semarang.

The nycthemeral cycle on the abundance shows a different influence depending on whether we are in the East or in the West (Fig. 3); outside the coastal border, the nightly effect on the abundance is weak; the nocturnal enrichment becomes very great along the Java coast.

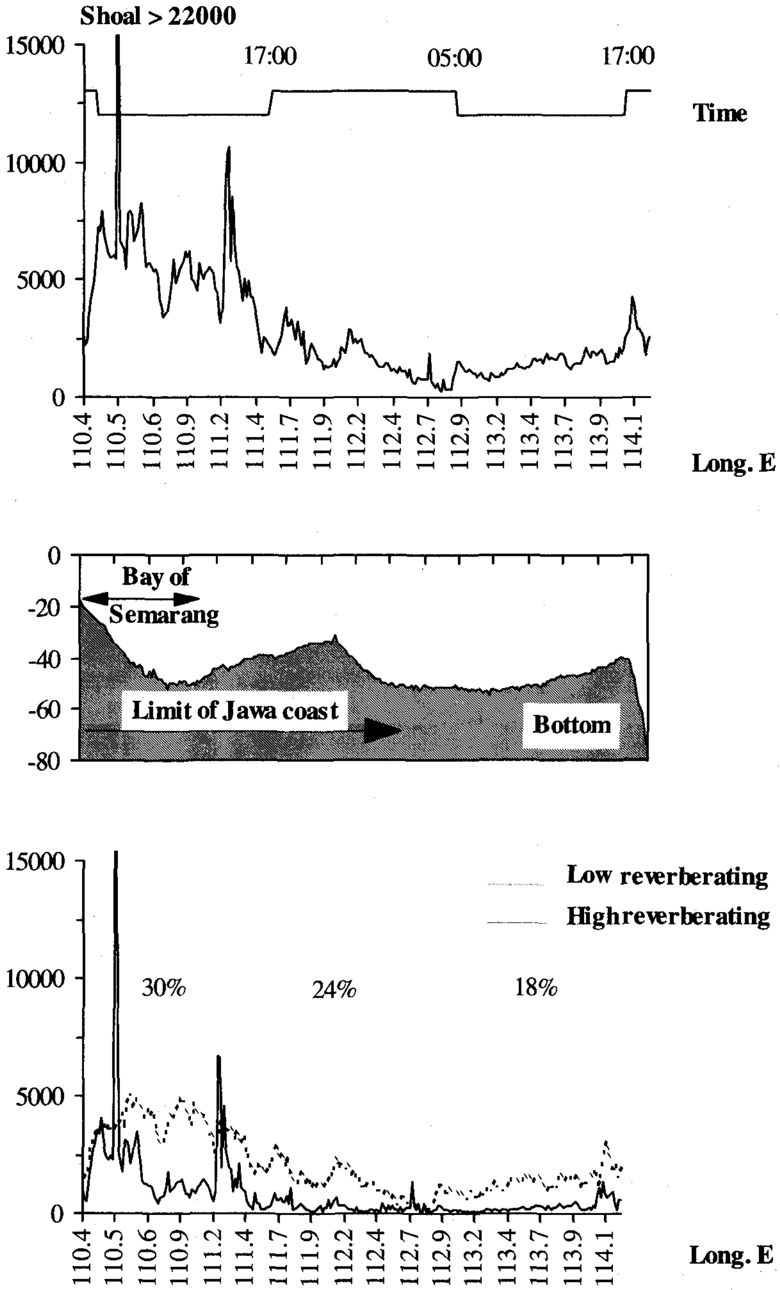

Figure 2 Density by mile (relative units) in February 1995, from Semarang to the East; up, total density, down, density relative to the high and low reverberating targets.

Gambar 2 Kepadatan (dalam unit relatif) per mil , Februari 1995, dari Semarang ke arah Timur; atas, kepadatan total; bawah, densitas terhadap tingkat reverberasi tinggi dan rendah.

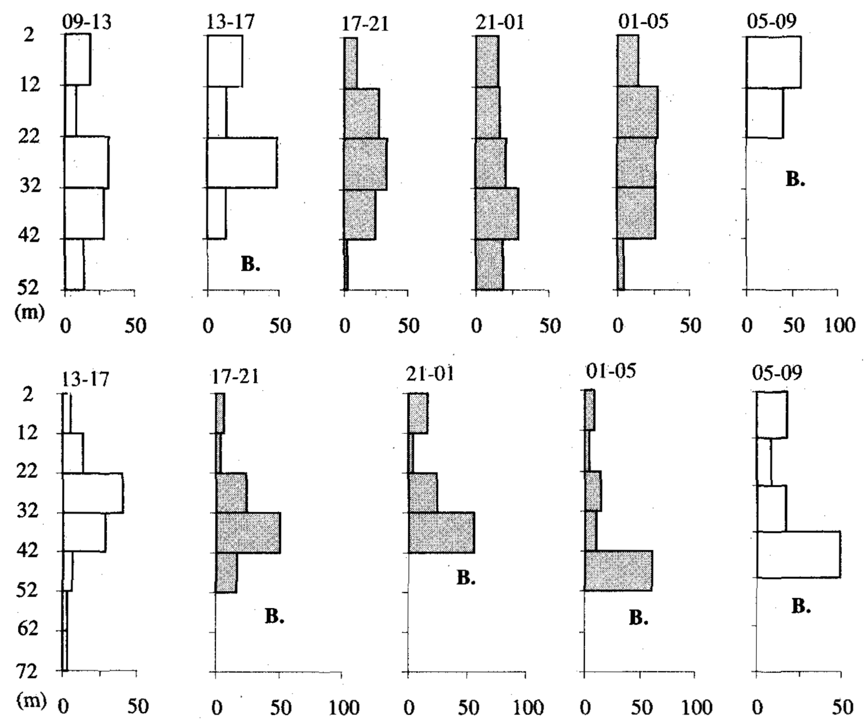

Figure 3 **February 1995 (Survey 52) : Diurnal vertical distribution of the density in percentage, along the east Java coast from Semarang (up) and out of the Java coast (down). (B. : position of the bottom).**

Gambar 3 **Februari 1995 (survey 52) : Sebaran tegak kepadatan diurnal dalam percen. Atas, sepanjang pantai dari Semarang ke Jawa Timur; bawah, lepas pantai. (B. : posisi dasar perairan).**

In February 1994, longer transects through the open sea were prospected (25 to 30 miles from the coast). In the East of Semarang, the densities are comparable to the ones in February 1995. In the West, by moving away from the coast, the densities decrease, suggesting that the high densities encountered in 1995, in the same sector of the bay, do not extend any more to the West (Fig. 4). In 1994 like in 1995, a great proportion of more reflecting targets in the surroundings of the bay is observed. The analysis of vertical distribution of density by layer of 10 m thickness indicates that the half of the deepest water is richer. As for the variation of abundance, a difference can be noted between the bordering domain of Java where the maximum of abundance varies in the depth between the night and the day (strong nocturnal vertical migration), and the eastern part where the maximum remains at the bottom all time. In February 1994, the same difference of nycthemeral behaviour is observed : permanent richness near the bottom in the East and vertical migration of the abundance with dispersion by night in the West.

Figure 5 represents the spatial and vertical distributions of the schools. Along the transect, the relation aggregation -- diurnal phase is clear, although such relation is less visible along the coast of Java; the aggregations are in the half upper water mass and the proportion of very small shoals (low reverberating) is dominant. It seems that there are 2 types of aggregations : those low reverberating which are dominant near the surface and those more reflecting without preferential localization.

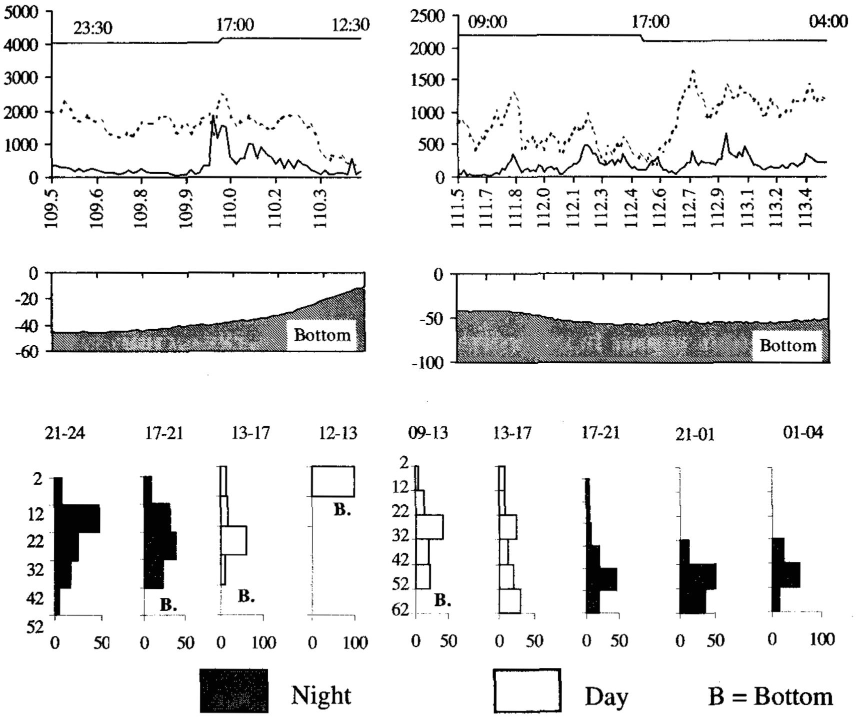

Figure 4 February 1994. Up, density per thousand (relative units) for low reverberating (dash) and high reverberating (line) targets, West (left) and East (right) of Semarang. Down, for each zone, the vertical location of the density, in percentage, related to the time.

Gambar 4 Februari 1994. Kepadatan (dalam unit relatif) reverberasi rendah (tanda hubung pisah) dan reverberasi tinggi (garis lurus), pada sebelah Barat dan Timur Semarang. Bawah, penanpang tegak kepadatan dalam percen menurut waktu dan zona.

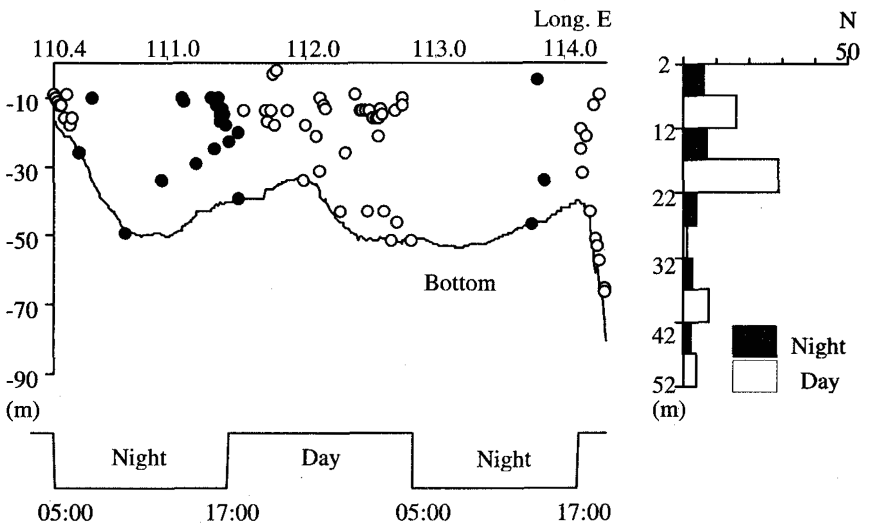

Figure 5 February 1995. Bathymetric distribution of shoals along the east Java coast and the global day night distribution (up); their location (down). The densities are in relative units.

Gambar 5 Februari 1995. Distribusi kelompok ikan berdasarkan kedalaman sepanjang pantai Utara Jawa Timur (Kepadatan relatif unit). Atas, distribusi global siang dan malam; bawah, lokasinya.

Survey of April 1994

It is a "Greek" survey from the coast to open sea, centered in the zone of the Bay of Semarang. The transects of 30 miles concern the depths from 15 to 50 m. Figure 6 represents the distribution of density per mile by day and night : on the one hand, there is a decreasing gradient from the coast to the open sea, on the other hand there is a very great nocturnal enrichment, which seems to take advantage of the coastal area. In fact, the representation of density variations along the distance coast-open sea shows that the nocturnal effect takes place particularly in a bathymetric sector of 25 to 40 m. That zone of nocturnal enrichment concerns the bay as well as the transects in the East of the peninsula. The variogram on the whole of data (day and night) indicates structures of about 20 miles of range, dimension probably in relation with the intervals where great variations of density are found along the transects. The variograms of abundance, diurnal or nocturnal, show the presence of structures lower than 10 miles, already observed previously in the Java Sea (Petit *et al.,* 1995).

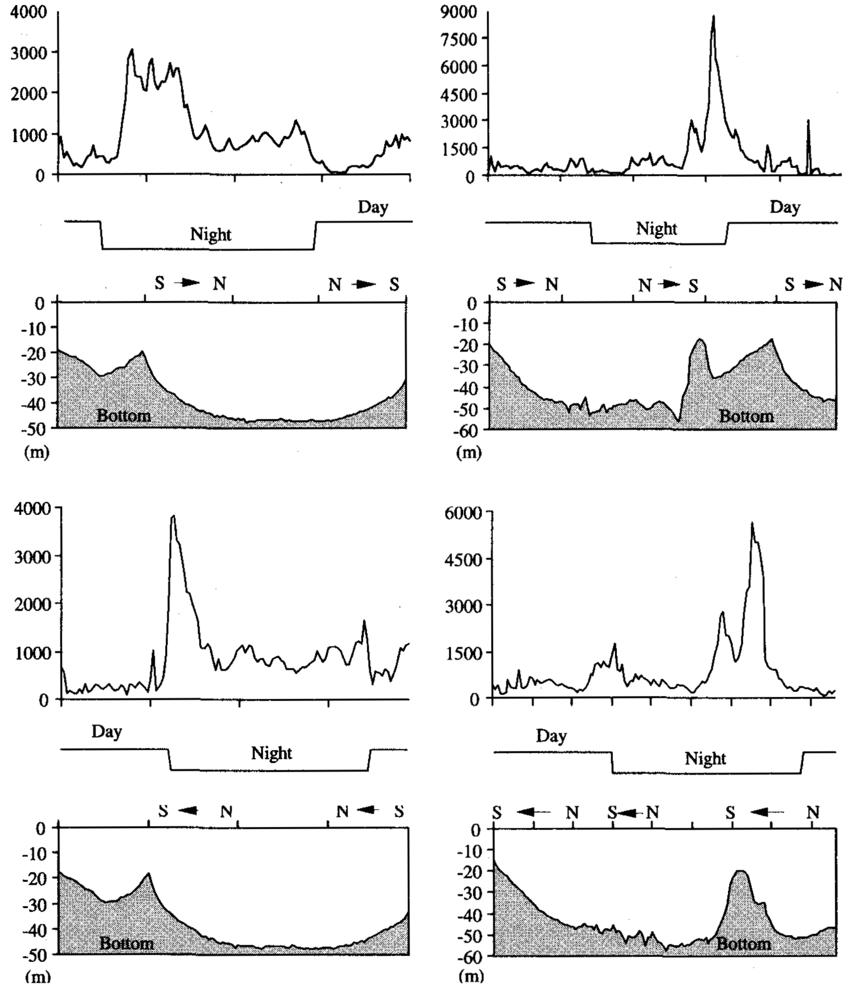

Figure 6 **April 1994 (Survey 42); Density per mile vs the distance. Left, go and back in the West of Semarang; right, go and back in the East.**

Gambar 6 **April 1994 (survey 42). Kepadatan per mil menurut jarak. Kiri , ulang-alik bagian Barat; kanan, ulang-alik bagian Timur Semarang.**

The vertical distribution of density (Fig. 7) is basically the same in all the area : the densities are higher in deeper half water mass, with tendency to dispersion of fish by night; the phenomenon is only greater in some bathymetric sectors.

The geographical localization of the shoals shows a gradient : they are more abundant and less reverberating in the coastal zone and in the bay (Fig. 8). The most remarkable is their bathymetric localization : the majority is in the deeper half water mass; because of absence of environmental data, it is not possible to suggest an explanation to the phenomenon; in the western part of the Java Sea the vertical distribution of the aggregations is almost the same.

In the East of the bay (Fig. 9), it seems that there are 3 sub-groups of aggregations : the low reverberating shoals which are present everywhere, the 2 other groups more reverberating, one in the open sea, the other closed to the coast. These latter are separated by the bathymetric zone occupied by high nocturnal densities.

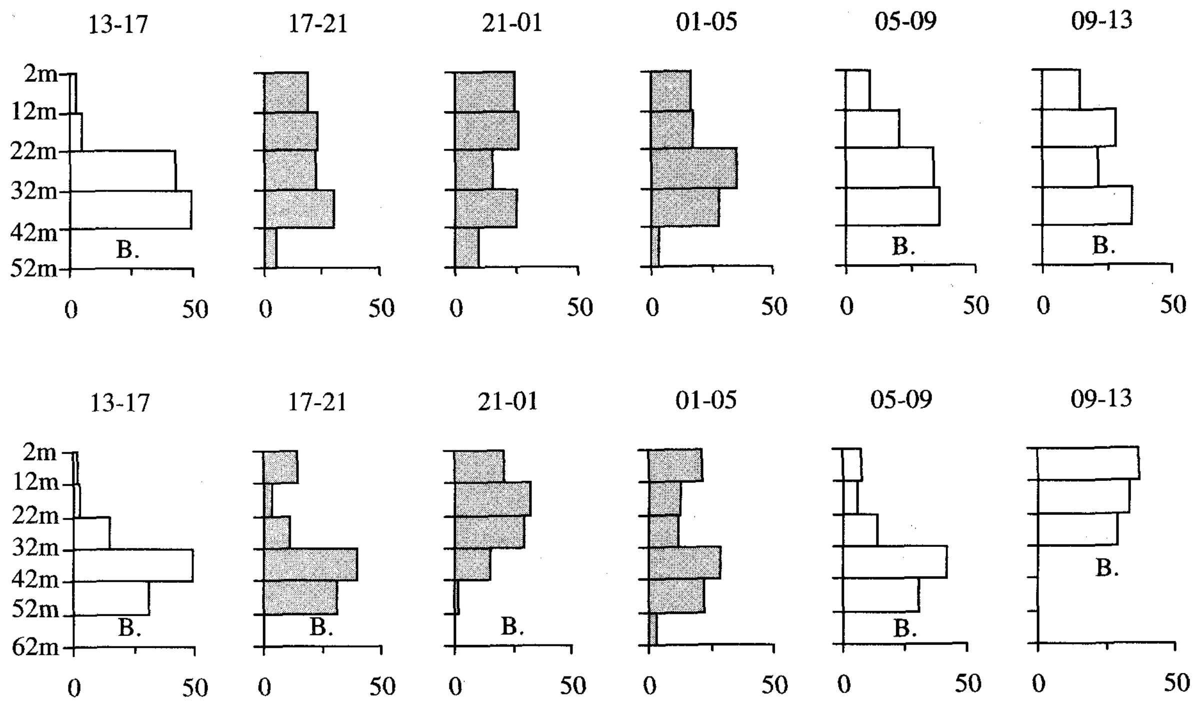

Figure 7 **April 1994. Diurnal vertical distribution of the density, in percentage, West (up) and East (down) of Semarang (B., position of the bottom).**

Gambar 7 **April 1994. Distribusi tegak kepadatan diurnal, dalam persen : atas, bagian barat; bawah, bagian timur Semarang (B. : dasar perairan).**

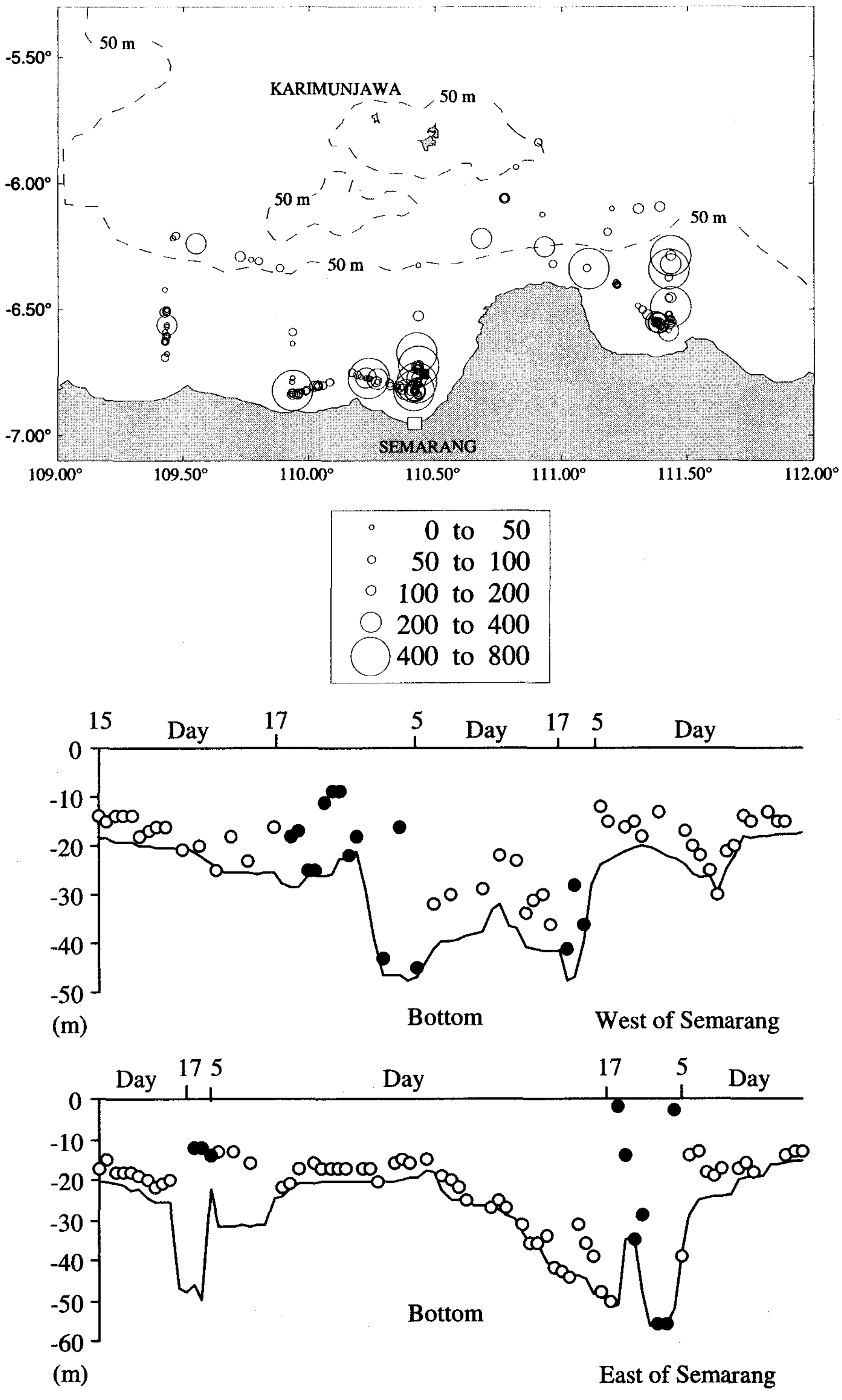

Figure 8 Up, location of shoals in April 1994 around the Bay of Semarang. Down, their bathymetric distribution in the West and in the East of the Semarang longitude.

Gambar 8 Atas : lokasi kelompok ikan pada bulan April 1994 di perairan sekitar Semarang; bawah : sebaran membujur kedalaman perairan di bagian barat dan timur Semarang.

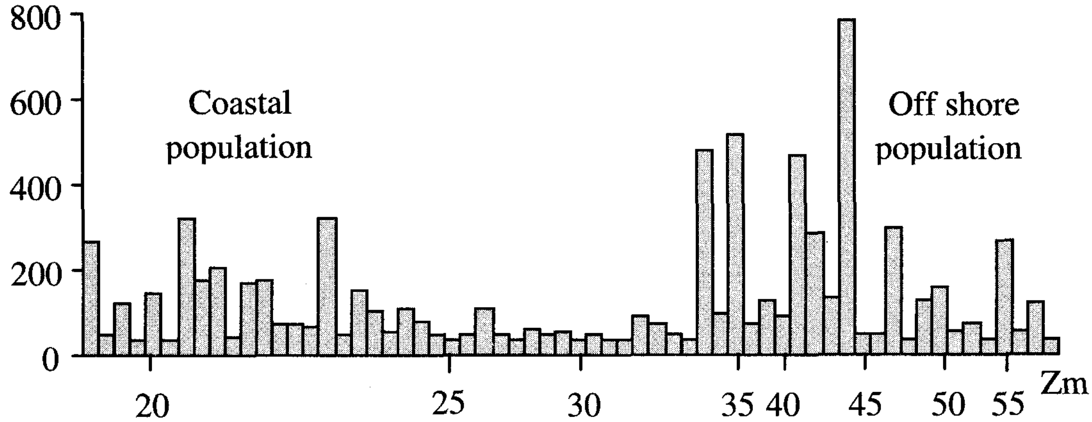

Figure 9 **April 1994, density of the shoals vs depth the East of the peninsula.**
Gambar 9 **Sebarang kepadatan kelompok ikan menurut kedalaman di perairan sebelah timur Semenanjung (Mandalika).**

Survey of May 1995

The survey has been realized when the haline homogenization of the Java Sea is intensified. It is a go and back along the coast of west Java, with two transects towards the open sea, on the eastern side of Sumatra (Fig. 1). In the West of Java, the transects are at 15-20 miles from the coast, by depth of 25 to 45 m (65 m in front of Sunda Strait). In Sumatra, the transects coast-open sea are of 60 miles (depth between 15 and 25 m). All along the route, the vertical salinity varies a little (32.2 to 32.8‰).

Along the western coast of Java (Fig. 10), the variations of abundance are linked to the nycthemeral cycle and to the increase of bathymetry : the transects by night and in deeper areas are richer. It can be considered that going from the Bay of Semarang to the West, the densities tend to decrease, whereas the bathymetry remains the same. The increase in front of the Sunda Strait would be the fact of a new pelagic stock linked to the strait.

Along the western side of East-Sumatra, the go and back course is the same for the southern transect only. Away from the strait, the water becomes poorer along the coast as well as towards the open sea (depth less than 25 m). In the northern part, where the round trips have been different, the densities remain very weak, except in the farthest north-east where the densities are relatively important by depth of 20-25 m.

Apart from general poor condition of water, the most prominent aspect in all that area is the absence of nocturnal enrichment, contrary to the western part of Java. Here, by day and by night, the most superficial layer is the richest, while, in the western border of Java, more than two third of the abundance is localized in the deeper half of the water mass. The greatest proportions near the bottom have been found at the surroundings of the Bay of Semarang and at the proximity of the Sunda Strait, which are also the richest sectors.

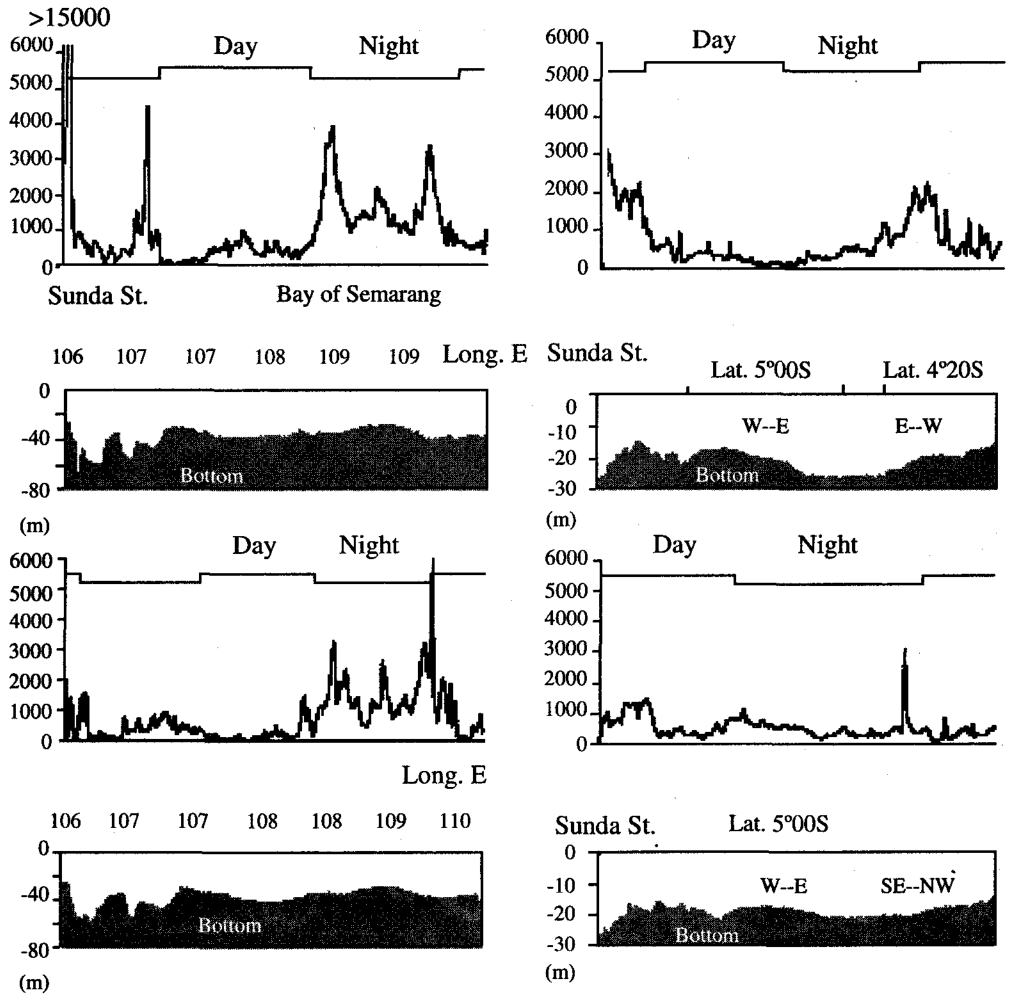

Figure 10 **May 1995 (Survey 53). Density by mile; left, along the west Java coast (go and back, identical transects); right, along the border of Sumatra, transects different.**

Gambar 10 **Mei 1995 (survey 53). Kepadatan per mil; kiri : sepanjang pantai Utara Jawa bagian Barat (ulang-alik lintasan yang sama); kanan : sepanjang pantai Sumatra (ulang-alik lintasan berbeda).**

The analyses of the shoals concern only the go-trip; the back-trip would bring only some supplementary information, because the courses by day or night are practically the same. Many shoals of very low reverberation have been found along the transects and only the most reverberating ones are considered, like in previous surveys. In the western side of Java, the aggregations seem abundant by day as well as by night and localized in the deeper part of the water mass (Fig. 11). The area near the Sunda Strait takes on its own characteristics with dense shoals by night and near the surface. Along Sumatra, the aggregations are exclusively present by day and their number is reduced (Fig. 12).

In the two previous surveys, the TS measurements have not been analyzed. In the survey of May, the calculation of averaged TS by station shows a regular decrease of the index from East to West (-52 to - 58 dB), with exception of a temporary increase in front of the Sunda Strait.

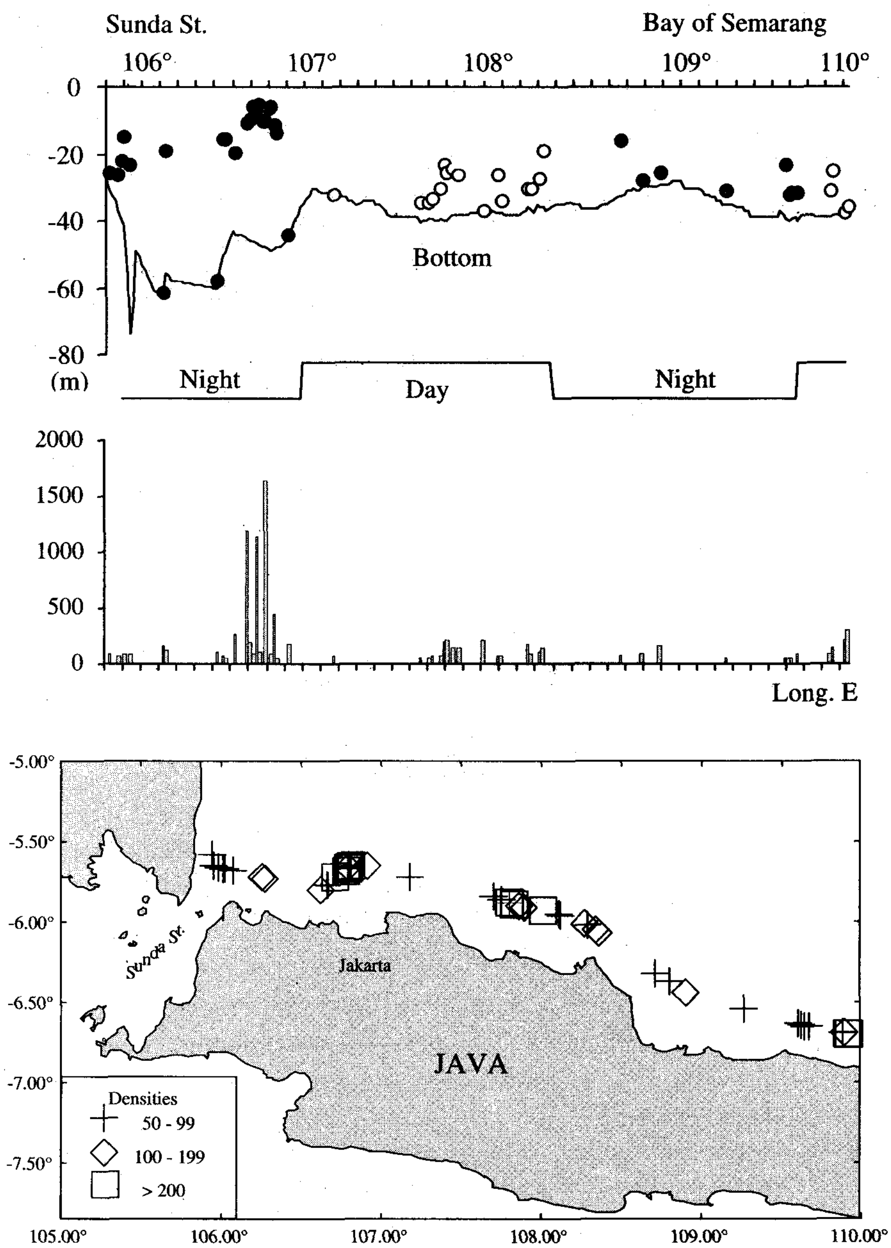

Figure 11 **May 1995. Up to down : bathymetric distribution of shoals from Semarang to the Sunda Strait, their relative density and location.**

Gambar 11 **Mei 1995. Atas ke bawah : distribusi kelompok ikan menurut kedalaman dari Semarang sampai Selat Sunda, kepadatan relatif dan lokasinya.**

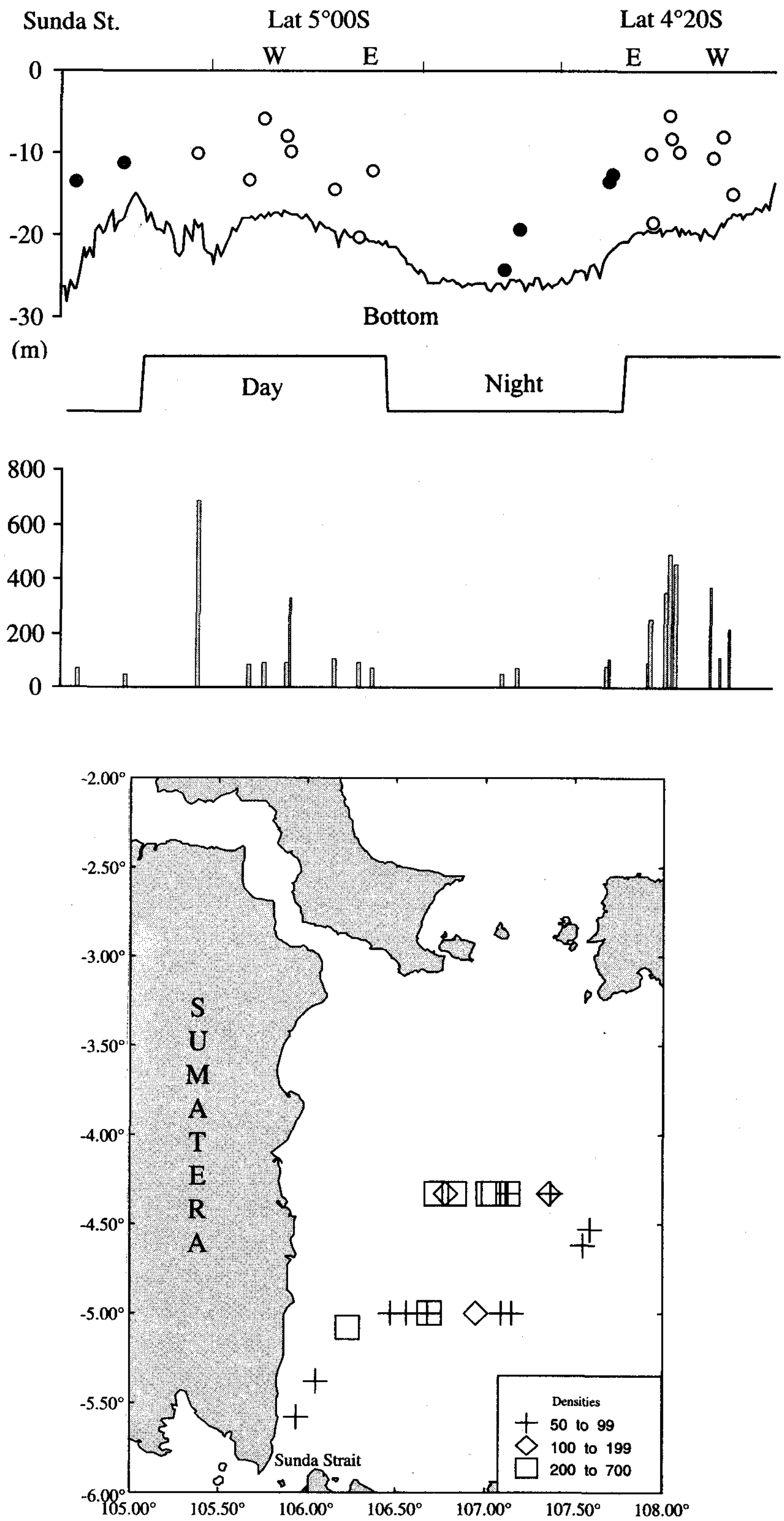

Figure 12 **May 1995. Up to down : bathymetric distribution of shoals on the border of Sumatra, their relative density and location.**

Gambar12 **Mei 1995. Atas ke bawah : distribusi kelompok ikan menurut kedalaman sepanjang timur Sumatra, kepadatan relatif dan lokasinya.**

CONCLUSION

Realized in different geographical zones and relatively near the coasts, the 3 surveys should have shown the influence of local environment (topography, particular coastal factors). From that fact, trying to extract the general characters can be risky. The Bay of Semarang with its strong density of small coastal schools and the values of very high global density seems to present a particular environment, similar to the case of the Sunda Strait sector, where we have found shoals of high reverberation at the surface, by night. On the other hand, the surveys took place in the seasonal periods which are not thoroughly comparable : the eastern area has been explored even though the effect of desalinization has not yet attained its maximum in the Java Sea, as it is the case in May for the exploration of the western part.

However, and even though the observations are still very fragmented, it seems that general characteristics can be extracted from this description, which allow to better understand the system of the Java Sea in its wholeness by integrating to those observations the local and seasonal particularities.

Till now the role of the bathymetry on the distribution of abundance and its relation with behavioural situations have not been much studied. Programmed for analyzing the environment in the fishing zones of seiners, the different surveys have been planned for prospecting the deepest sectors (and also the most monotonous) of the Java Sea. The survey of April 1994 in the Semarang area clearly reveals the existence of a nycthemeral migrating behaviour related to some bathymetric levels. But moving towards the East or the West from that bay, there is a similarity of situation which leads us to consider that the phenomenon is not local. The variations of nycthemeral density ratio, in the noted different sectors prospected, summarize well the behavioural differences and their consequence on the daily variations of abundance. In all that area, under direct continental influence, as soon as the bathymetry becomes deeper than approximately 50 m, the maxima of abundance are linked to the nocturnal vertical movements; the sub-superficial waters are the richest and during the nocturnal phase every layer of water is enriched by a semipelagic fauna. More to the open sea towards the East (February 1994, February 1995), the nocturnal effect becomes lower and the maximum of abundance remains near the bottom.

At the longitude of Semarang, the very coastal domain -- bottom less than 25 m -- has been prospected in February 1995. That strip of less than 10 miles, appears relatively poorer than the near open sea, at least by day, with a multitude of small schools, low reverberating. But in the coastal border of Sumatra, the same type of bottom represents an extension of more than 60 miles; it has been prospected by day and night; it appears very poor with a population remaining pelagic by day and night.

During those 3 surveys, there is a certain analogy in the characteristics and localization of the shoals; it is the presence of numerous small schools, low reverberating; these schools predominate in the coastal border, while the more reverberating shoals tend to be found in the more important depths. Particularly from East to West, the vertical localization of aggregations changes : in the East, they generally remain in the superficial half of the water mass; from Semarang to the West, they are deeper; their density decreases from East to West[1], all like the global abundance (Fig. 13).

[1] The number of aggregation by mile decreases : 0.4 in the east of Semarang, 0.3 in the bay, 0.2 in the west Java and only 0.1 alongside of Sumatra.

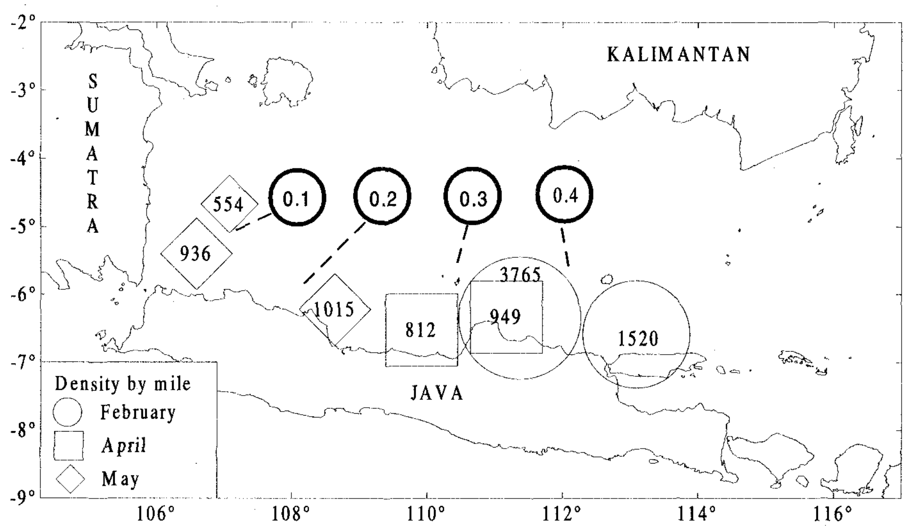

Figure 13 **Mean nycthemeral relative densities between February and May; in black circles, the number of shoals by mile in the 4 sectors : Sumatra, West Java, Semarang sector and East Java.**

Gambar 13 **Rataan « nycthemeral » kepadatan relatif pada Februari dan Mei; lingkaran hitam adalah jumlah kelompok ikan per mil pada 4 sub area : Sumatra, Bagian Barat Jawa, Semarang dan Bagian Timur Jawa.**

Nevertheless, those general characteristics come from observations which were realized during different months and they integrate a seasonal evolution that might have attenuated the similarities or, on the contrary, accentuated the general tendencies, like the impoverishment from the East to the West, including the local and seasonal particularities. The existence of rich pelagic and semipelagic populations in the zone of the Semarang-Karimunjawa Islands, probably can be linked with the seasonal persistence of water with higher salinity in February; the presence of new pelagic population in front of the Sunda Strait, original by the importance of aggregations and by their behaviour reminds us that the Java Sea is an open domain which suffers and takes advantage from seasonal migrating flux.

It remains to confront those results with biological knowledge about the group of species, also with the comprehension of the dynamic mechanisms of the area as they appear in the follow-up of previous analysis. Among the commercial species the most abundant caught by seiners, there is one more semipelagic : *Decapterus russelli.* As a target species, it seems to have greatly contributed to the development of the present fishing technique with light attraction. It is likely that this latter contributes for a great part in the abundance detected in the bottoms of 25 to 50 m along Java. So, in wet season, that species would occupy, for the most important part, a bathymetric stratum, perhaps in relation with the environmental tolerances and trophic requirements : the supplies in nutriments are then essentially continental. The most coastal border, subject to seasonal desalinization would be occupied by a fauna with pelagic dominance and more adapted. The mackerel *Rastrelliger spp.* and certain sardines belong to that fauna.

In a tentative of modelization, the previous works concerning 2 large surveys (October 1993 and February 1994) have come to define 3 strata of associated populations (Petit *et al.,* 1995) : the first, oceanic, does not concern the domains studied here (except probably the Sunda Strait and the extreme East of Java). According to the season; the second stratum, neritic, occupies the major part of the Java Sea. The third, the coastal stratum, had not be sampled correctly; but strong seasonal desalinization justified its existence along the coast.

The behavioural study, moreover, had enabled to recognize 2 different populations : one pelagic, ubiquitous and another one semipelagic responsible of high densities in the dry season. This latter is following a longitudinal movement according to the seasons.

Besides the fact the study of those 3 surveys globally corroborates the previous hypothesis, it also brings out some interesting precision in the domain of ecology as well as in the seasonal migrating movements. The coastal stratum occupies, at least in front of Java, a very restricted surface (fifteen miles maximum). The important extension of shallow waters in front of Sumatra, inhabited by this stratum, seems to contribute to the impoverishment of the West Java Sea. What about the South of Kalimantan where the zone of shallow depth is also large? In wet season, this zone is less occupied by semipelagic populations. At last, it was assumed that the populations migrate to the East, at the beginning of the wet season. It appears, from the high densities met in front of Semarang, that one part, sedentary, makes a migration to the South to stay in some favourable bathymetric sectors.

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Discussion

(Chairman Dr. Pasaribu)

Dr. Eddi Amin

Q : - Usually, we use the values of density for stock assessment. I would like to know how you convert the value of Target Strength to fish density. Did you use the results of fish calibration or common formulas ?

A : - Tomorrow, we will have another communication about the conversion of relative density values to absolute biomass with many restrictions. To have this information, we made experiments in cage, and we measured the Target Strength of three species. We selected the best data to calculate our constant of conversion. We will see that also tomorrow.

TARGET STRENGTH MEASUREMENTS ON THREE PELAGIC FISHES FROM THE JAVA SEA[1]

P. COTEL, D. PETIT

ABSTRACT

Using acoustics for biomass evaluation, the back scattering cross section of species has to be determined to convert the data into weighted values. During the cruises of EU Project "Java Sea Pelagic Fishery," TS measurements on 3 pelagic fishes of economic importance : *Decapterus russelli, Selar crumenophthalmus, Rastrelliger kanagurta* were carried out, using a BioSonics dual beam echo-sounder at a frequency of 120 kHz. The observations on single or multiple targets in a cage, revealed a large dispersion of the responses, even in the same experiment. These results are discussed and compared with Johannesson's (Anonymous, 1984) in the same area.

KEYWORDS : Java Sea, pelagic fishes, acoustics, methodology, Target Strength.

ABSTRAK

Penggunaan akustik untuk evaluasi biomassa, harus diikuti oleh penentuan "back scattering cross section" dari jenis ikan sehingga data dapat dikonversikan ke dalam nilai bobot. Selama beberapa pelayaran proyek EU, PELFISH, dilakukan pengukuran 3 jenis ikan ekonomi penting : Decapterus russelli, Selar crumenophthalmus dan Rastrelliger kanagurta *dengan menggunakan BioSonics bim ganda 120 kHz. Pengamatan terhadap target tunggal atau beberapa target dalam suatu kurung-kurung mengungkap adanya respon yang bervariasi, meskipun dalam suatu percobaan yang sama. Hasil pengamatan ini dibahas dan dibandingkan dengan hasil Johannesson (Anonimous, 1984) di area yang sama.*

KATA KUNCI : Laut Jawa, perikanan pelagis, akustik, metodologi, Target Strength.

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

With the calibration of acoustic equipment, reflection index measuring of live fish constitutes the first stage in the evaluation of abundance. This operation should allow the adjustment of the threshold on the echo voltages which are to be taken into account. It should also allow the calculation of a conversion constant of integrated voltages during prospecting of biomass measuring. The following observations were made during the "Java Sea Pelagic Fishery Assessment" Project.

MATERIALS AND METHODS

Three series of measuring have been made during the season when pelagic fish abound in the Java Sea : November 1991, October and December 1992. The success of these experiments is dependent upon strict environmental conditions : the location has to be deep and sheltered from the wind and currents; it must moreover be close to a fishing zone. Only 2 places in the Java Sea were found to be acceptable : Bawean Island and Matasiri Island. The former, 17 m depth, in a bay, was the best.

The measurements were made with a Dual Beam BioSonics echo-sounder (7° narrow and 18°wide circular beams). The acoustic characteristics of the equipment were controlled previously on a standard tungsten ball of a -41 dB reflection index. Characteristics and adjustments throughout the measurements were the followings :

- Transmitter Source Level : 222.54 dB/µPa/m
- Narrow beam Receiving Sensitivity : -173.13 dB/V/µPa
- Wide beam Receiving Sensitivity : -172.17 dB/V/µPa
- Pulse Duration : 0.4 ms
- Ping Rate : 3/second
- Threshold : 100 mV
- TVG : 40 Log R + 2 αR
  with α = 34.7 dB/km
  and R = 125 m

In order to keep the fish in the acoustic beam, the latter is introduced into a conical cage specially built in order to be not disturbed by the reflecting contribution of the lateral surface. The transducer is an integral part of this cage (Fig. 1). In this way, the transmitted signal is not attenuated by the net, the cage is sufficiently spacious to permit the movement of the fish and to record the echoes without interference. The measurements were taken from three pelagic species, among the most exploited in the Java Sea : *Decapterus russelli, Selar crumenophtalmus* and *Rastrelliger kanagurta.*

The three species have a swimbladder. The fish were introduced into the cage in sets of 1, 2, 4 or 6; the cage was then submerged. Reverberation measurements were taken night and day.

RESULTS

Dispersal of measurements

The most significant aspect from these experiments is the dispersion of the values that considerably masks the existence of a relation between the reverberation index and the size of targets, on the short interval of length (11 to 17 cm). Figure 2 represents the distribution of Target Strength measurements of *Selar* between 12 cm and 17 cm (fork length). The same dispersion can be observed with *Decapterus* and we saw no notable decline in this dispersion according to the number of measurements.

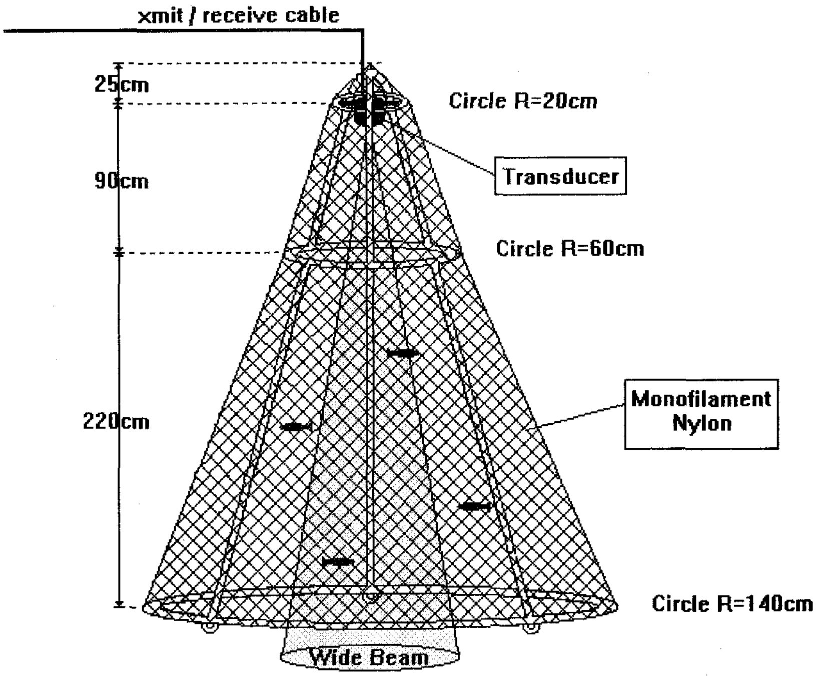

Figure 1 The live fish calibration cage.
Gambar 1 Kurung-kurung untuk kalibrasi ikan hidup.

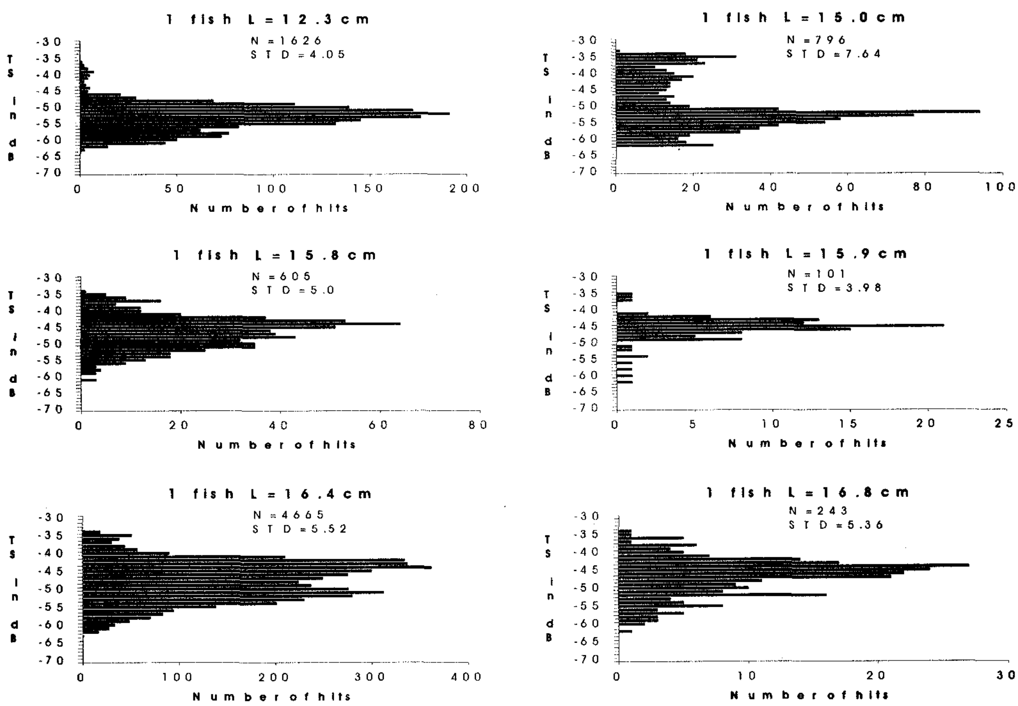

Figure 2 TS related to the size.
Gambar 2 TS dikaitkan dengan ukuran.

Figure 3 represents the distribution of Target Strength values of *Decapterus* when 1, 2 or 6 fish were introduced into the cage. The standard deviation is of the same order as in the first experiment. No notable changes in behaviour were noticed between the observation on one fish and several : the "group effect" did not seem to influence measurements.

"Swimming Activity" effects

The influence of the position a fish takes in the sonar beam on its acoustic response is known (Love, 1971 and 1977; Nakken and Olsen, 1977). The acoustic response is the strongest laterally. In dorsal detection the reverberation index can vary to more than 10 dB according to the fish tilting (in less than 15°). In classic prospecting conditions, such variations can be attributed to different species as well as the inclination of the same species if we do not have simultaneous visual information. Observations carried out on the isolated fish in the cage gives us knowledge about the vertical location and the acoustic response. By using the results of an experiment on *Selar*, we put the reverberation index and the vertical positioning of the fish in relation (Fig. 4a).

From ping to ping, the position slightly changes and suggest very low swimming activity. The dispersion of index values is slight as well. On the contrary, in the same series of values, while selecting events where the fish shows a significant vertical movement, the corresponding index values show a strong dispersion (Fig. 4b). Owing to an intense swimming activity, the fish enters the sonar beam in different positions which leads to strong index dispersal.

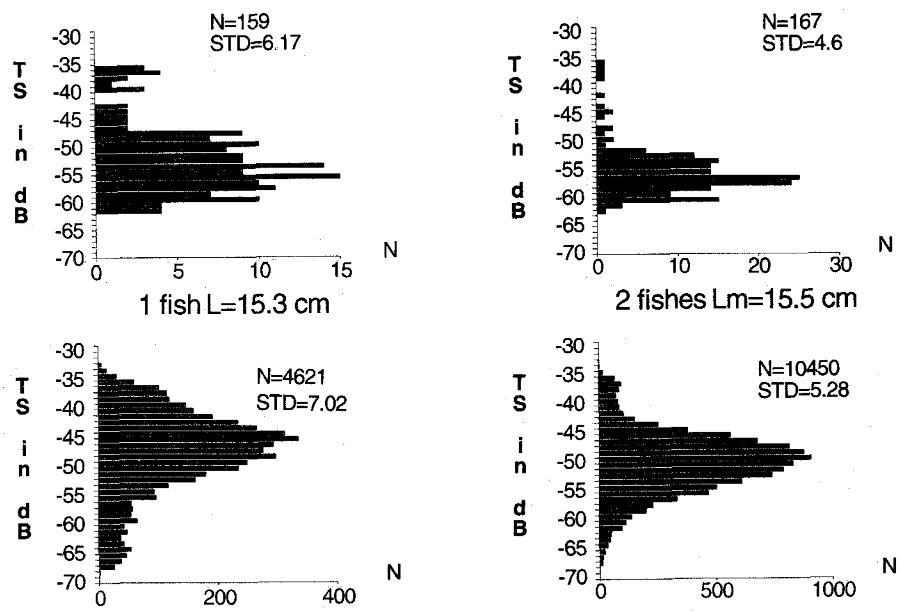

Figure 3 **TS related to the number of fish, Lm = mean Fork Length.**
Gambar 3 **TS dikaitkan dengan jumlah ikan, Lm = rata-rata panjang standar**

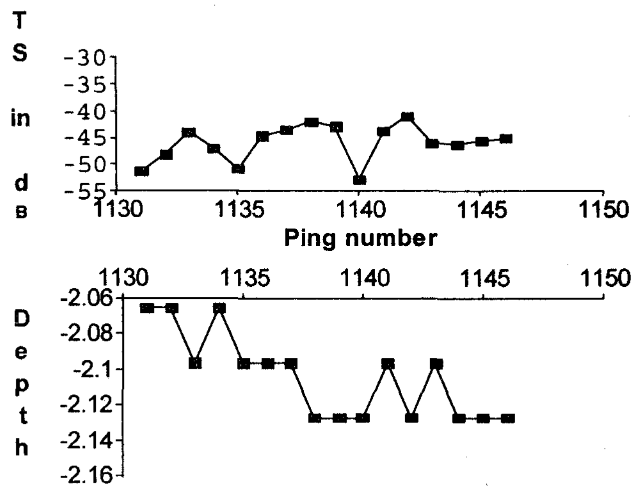

Figure 4a TS during low swimming activity.
Gambar 4a TS selama aktivitas berenang yang rendah.

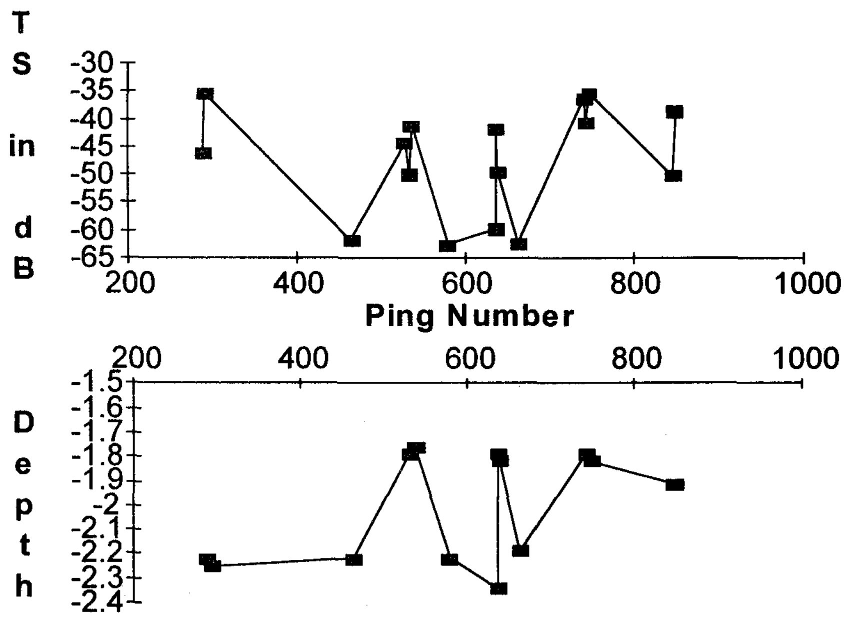

Figure 4b TS during high swimming activity.
Gambar 4b TS selama aktivitas berenang yang tinggi.

Influence of external factors

Under normal acoustic prospecting conditions, the influence and effects of disruptive external factors are generally difficult to bring to light. The state of being confined in a cage can in itself have a considerable effect. We assume that since the length of time necessary for measurements is short, this effect is only slightly disruptive[2]. The animal becomes used to its environment and the noise.

The effect of light during prospecting was noted in some experiments (Levenez *et al.*, 1987; Gerlotto *et al.*, 1990) and the authors consider that it tends to polarize the fish more than generate an escape reaction. In the region, light is used to gather the fish together which makes it easier to catch them.

Figure 5 shows the reactions of 1 group of *Selar* to the light. The experiments took place at about 10 PM. In the first experiment, a 400 watt lamp attached to the rail, lit the cage which was submerged at about 3 meters. In the second experiment, a 1,000 watt lamparo was used. It was placed at 2 m under the cage; in the third, it was pitch-black.

In the first 2 experiments, the fish showed from the position they took in the cage, that they tend to avoid the light and that swimming activity is reduced. When darkness is back, the echoes are dispersed in the cage space; swimming activity is increased. Even though the experiment was brief, it shows that light, in provoking a reaction, can bias index measurements.

Adjusting the equipment

Reverberation index measures require first that the acoustic characteristics to be known exactly. In the case of dual beam sounder, one part of these controls (source level and receiving sensitivity) is facilitated by the use of a tungsten ball as the standard target. However, the choice of electric level of the signals that are taken into account for index measurements is up to the operator. Use of a threshold that is too high risks suppressing the low reverberation values, truncating the distribution histograms.

Recorded with a 100 mV threshold, certain measurement series were played back with a 300 mV threshold. Table 2 summarizes the results and shows that the elimination of low values has a more or less significant effect according to the average index value and the dispersion. In our experiments, distribution histograms of index values are not shortened in respect of the weak values. It indicates that the chosen threshold (100 mV) was correct, taking into account the acoustic performance of the equipment.

Among the series of observations, we chose, as the most likely, the average reverberation index values in experiments where several animals were present and where the targets showed a fairly homogeneous distribution in the space of the cage.

The average values observed are :

D. russelli : TS = -47.7 dB (Lf = 16 cm)

S. crumenophtalmus : TS = -44.9 dB (Lf = 16 cm)

R. kanagurta : TS= -50 dB (Lf = 11 cm) but this value concerns a small number of values.

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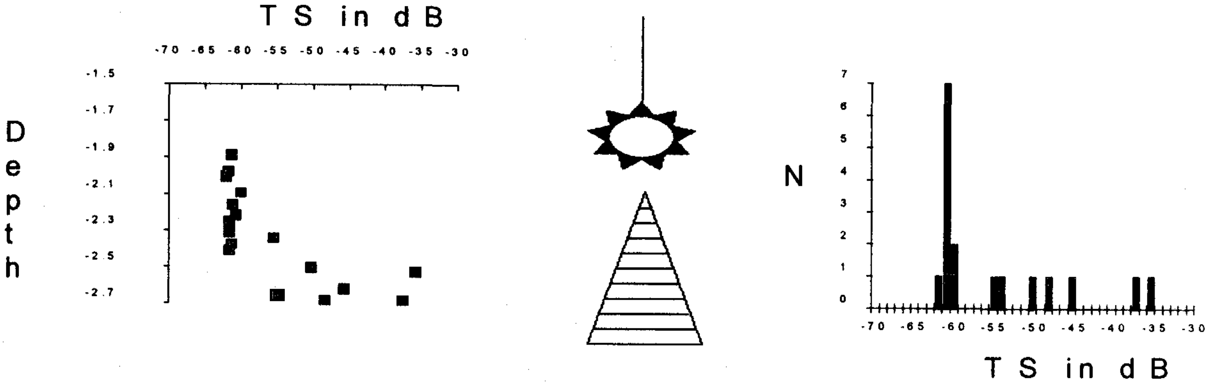
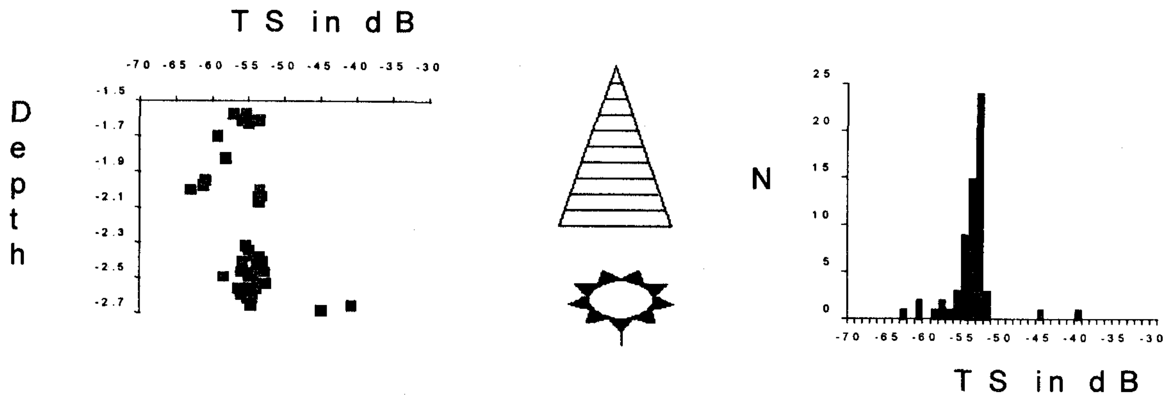
[2]Unless behaviour is visibly such that measurements can not be taken : permanence out of the acoustic beam or permanently random activity.

1-Light "ON" above the cage (*cahaya dinyalakan di atas kurung-kurung*).



2-Lamparo "ON" below the cage (*cahaya dinyalakan dibawah kurung-kurung*).



3-Light "OFF" (*cahaya dimatikan*).

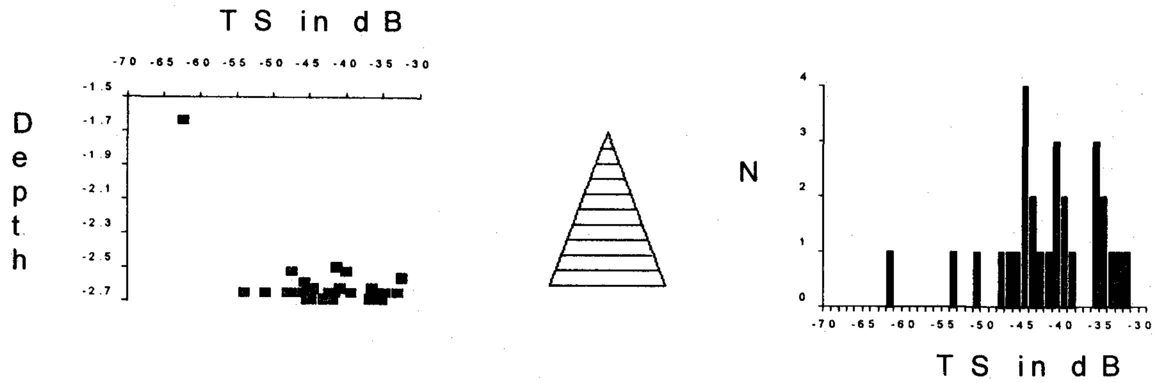


Figure 5 Light Influence.
Gambar 5 Pengaruh cahaya.

Table 1 Index values related to the threshold.
Tabel 1 Nilai indeks hubungannya terhadap "*threshold.*"

SPECIES	LENGTH cm	INDEX values Threshold 100 mV	Threshold 300 mV
Decapterus	12.5	-47.7 dB	-46.9 dB
	14.2	-47.5 dB	-45.4 dB
	14.3	-44.5 dB	-43.8 dB
	15.3	-47.4 dB	-42.3 dB
	15.5	-51.4 dB	-42 dB
	15.7	-48 dB	-45 dB
	16.2	-47.7 dB	-47.1 dB
Selar	12.3	-51.3 dB	-47 dB
	15	-43.6 dB	-39.5 dB
	15.8	-44.2 dB	-42.6 dB
	15.9	-44.7 dB	-43.9 dB
	16.4	-44.9 dB	-42.7 dB
	16.8	-44.4 dB	-42.8 dB

CONCLUSION

Reverberation index measurements are necessary for acoustics to define the conversion constant of reverberation measurements on biomass. In the past, echo-integration was made on known quantities of fish introduced into a cage. This relatively simple method was not without risk : imprecision about the space really occupied by the fish, handling important quantities, incidence on measurements of minimal occupation space acting by means of behaviour (Foote, 1980a), death, possible multiple reverberations or shadow effect, besides reverberation on the surfaces of the cage of which the importance was only approximated (variable in time).

The development of new equipment (dual beam or split beam) and the computerization of signal data processing have allowed the use of a semi-automatic system of measurement and the development of software data processing. The fact remains, nevertheless, that the operator should always perform measurements with calibrated equipment.

The behaviour plays a very important role, that is why reverberation indexes are usually measured in a natural environment. In this way, the interference of uncontrollable behavioural reactions produced by confinement in a cage are avoided.

Except the remaining exceptional situations, measurements *in situ* without simultaneous visual control cannot guarantee a value corresponding to a particular size-known species. According to the catches in the Java Sea, 5 dominant species live together; an imprecise knowledge of their geographical habitat and behaviour does not allow us to attribute the measurements to a given species.

On the other hand, in the calculation of the weight conversion constant, we tended to use an index value which was close to the maximal response. The latter was considered to be the one produced by the fish in a normal position in the acoustic beam[3]. For a dozen years, acoustic response measurements related to the orientation of the target have been performed (Foote, 1980b) in order to calculate an index according to the most probable directivity of the fish. In situ, these kinds of observations are obviously rare, given the slight chance of encountering favourable conditions and the difficulty of getting the logistics. Very recently, observations on herring (Hamre and Dommasne, 1994) showed that in the reproductive phase, the reverberation index would be more low, in this specific case.

The choice of an index value should then be defined according to the predicated use (Foote, 1987). In our case, we tried to define an index destined for weight evaluations on "classical" prospecting. To reduce a possible effect of being confined in a cage or isolated behaviour, it is recommended to increase the observations made up of a large number of measurements. The procedure aims to obtain an average index value corresponding to the most frequent position. Our observations show that optimal response values are found to be far away from the mode or the average. It indicates that the stongest echoes are not on average representing the usual position of the fish. In the Java Sea, shoals are not numerous; the fish are scattered. The nycthemeral density variations are strong; they suggest important vertical movements throughout the diurnal cycle. The behaviour observed in the cage, where the fish sustains considerable swimming action, does not seem to contradict the distribution and vertical movements observed *in situ.*

Until now, the great majority of index measurements has concerned the species of the North Atlantic stocks with sizes that greatly exceed the tropical pelagic ones. In operating on caged fish (measurements in 20 log function), Johannesson (Anonymous, 1984) had obtained -45 dB on the same or related species (*D. russelli* or *D. kuroides*), at the same frequency. Other experiments are still necessary to complete the first results.

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[3]Using a great quantity of encaged fish, we tried to make sure that the fish "turned", having then a behaviour close to the one observed in a natural environment while the fish is in shoal.

DISCUSSION

(Chairman Dr. WIDODO)

Dr. ILAHUDE

- What is the maximum depth where you cannot get any longer the echoes ?

The Time Varied Gain function, which corrects all the echoes, has a dynamic range of 125 m. We can, of course, detect targets beyond this range, but their responses are not corrected any more, acoustically speaking. This range can be modified by changing the settings of the receiver PC board of the echo-sounder; it can be set from 2.5m up to 250 m or more. We chose these settings of 125m dynamic range to match with the bathymetric conditions of the Java Sea and to get the highest resolution.

Dr. GERLOTTO

- You said, in the conclusion, that the average Target Strength of a single fish is far from the optimal value. What are your recommendations for using these -47.7 dB in the field ?

- In our case, we tried to define an index destined for weight evaluations on "classical" prospecting. We tended to find a value which was close to the maximal response and also, in the mean time, the expression of an average condition in the field : this index was considered to be the one produced by the fish in a normal position, more precisely in the horizontal position, within the acoustic beam. We may consider that this normal position is generally the most common encountered *in situ*. This normal or "average" position corresponds to a quiet moment of swimming activity. After lots of measurements, we selected these periods of quietness and we compared them with the mode we obtained within this wide distribution. Fortunately, these Target Strength values were very close to the peak of this mode, confirming, therefore, that the mean value was the expression of an average behaviour. Doubtless, I do think that this index can be applied in the field, and input for echo-integration calculation. Our conversion factor has been determined from this value.

Dr. PETITGAS

- You showed us that light affected the TS value and you gave an interpretation that, maybe, the fish were polarized because of light. Nevertheless, you are using mean TS value. After having seen echograms during light attraction experiments, where there are a lot of concentrations, how can the TS increase because the fish is polarized ? Could the TS double ? I understand that, maybe, we should use one TS for the night and one TS for the day.

- For light attraction, it is hazardous to apply any values, because you always have overlapping echoes, saturation, reflection of energy within the concentrations in many ways. It is quite impossible to use one mean value for all the schools randomized below the transducer. The aim of this light attraction as a part of the cage experiment, was to complete the study of fish behaviour, more precisely the polarization effect. According to the first results, the fish tend to avoid the light beam; it does not mean they cannot stand it. We may suppose that this light focusing on the cage, was too close and hot, 400 watts and 1000 watts. It appears that they tried not to be right beneath the focal of the light and also that the TS values were quite steady; it leads to think that they were polarized; they did not swim, they seemed to be weak and tried to go out from the acoustic beam. We have collected data, during this light experiment, maybe biased because they look tilting. These results should not have to be extrapolated to the classical survey conditions. Even if the role of lights of a vessel is not negligible, the impact of these latter is far less than the one during our experiment. The closeness of the lightning, during the cage experiment, did not reflect the natural conditions; it amplified the phenomenon in such a way that this polarization likely has become a kind of stress. We should reconsider the term "polarization" in our case.

It is well known that TS values, at night, are higher than during the day. Many presumptions can be evoked : different species, different behaviour,... There are so many parameters that I dare not to recommend the use of two Target strength values, one for the day, one for the night. As far as we know, we must be careful and repeat again in deep the experiment *in situ*, on mono-specific and well-known stocks, under normal survey conditions.

Dr. MASSE

- Did you make experiments to compare the Target strength values (of one species) of one fish and lots of fish, in order to try to see the evolution of the TS, regarding to the number of fish, alone and when fish is in school ?

- At the end of the cage experiments, we put the rest of the spare fish in the cage, randomly. I have not yet postprocessed the data; I cannot say, at the time being, how is the evolution of the TS values regarding to the number of fish, until a probable and sudden saturation level. Besides the cage experiment, we only performed *in situ* measurements. TS values *in situ* are still reliable even when the fish are aggregated; the system is able to discriminate the echoes one by one, if the density is not high. By the way, the former value of -47.7 dB has been often met. When a big and very dense school is encountered, the system refuses the received echoes considered as non single targets; many discrimination criteria filter the received echoes and theses latter are rejected if out of limit; the few results, which succeed to break through the test, are biased because of multiple interacting echoes.

WEIGHT CONVERSION OF THE INES MOVIES ACOUSTIC DENSITIES AND THE THRESHOLD EFFECT ON BIOMASS EVALUATION

D. PETIT, P. COTEL

ABSTRACT

The detection and the reverberation measurement of the fish by Acoustics allow to analyze their behaviour, distribution and structures. All these investigations are mainly based on a relative evaluation of densities. The method of echo-integration also allows to quantify abundance. It then necessitates to know accurately the acoustic performances of the apparatus and the definition of a weight conversion coefficient to apply on the relative data.

The Ines-Movies system, used during the acoustic surveys of the PELFISH Project, consists of a calculation procedure with conversion coefficient. After determination of the *Decapterus russelli* reverberation index (or TS), in cage this coefficient has been calculated. The accuracy of evaluations resulting from such an index depends particularly on the TS one. But another parameter has to be taken into account; this is the adjustment of threshold during the prospecting. Even with a controlled adjustment of this latter, the conversion of relative integrated values of the Java Sea shows that the evaluations obtained in that way do not correspond to the richness of the area, according to fishing techniques, the level of commercial captures, and the results of experimental fishing as well. The playback of the rough data, available in the Ines-Movies system, allows to better adjust the threshold for evaluation of the targets, taking into account the reverberating surrounding conditions.
KEYWORDS : acoustics, pelagic fish, Java Sea, weight conversion, biomass.

ABSTRAK

Deteksi dan pengukuran pantulan gema ikan secara akustik memungkinkan untuk menganalisis tingkah laku, penyebaran dan struktur ikan. Semua penelitian tersebut di atas terutama didasari oleh evaluasi kepadatan relatif. Metode integrasi gema juga memungkinkan untuk membantu penghitungan kelimpahan. Karenanya perlu untuk diketahui secara akurat kinerja peralatan akustik dan definisi koefisien konversi berat bagi data relatif.

Sistem Ines-Movies yang digunakan proyek PELFISH selama penelitian akustik, terdiri dari prosedur penghitungan dengan perubahan koefisien. Setelah penentuan indeks gema Decapterus russeli (TS), di dalam kurung koefisien ini telah diketahui. Ketilitian dari evaluasi sangat tergantung dari nilai TS. Tetapi, ada parameter lain yang harus diperhitungkan, yaitu penyesuaian ambang selama pencarian. Bahkan dengan pengawasan yang sesuai terhadap hal yang disebut terakhir ini, perubahan konversi nilai kesatuan relatif di daerah Laut Jawa menunjukkan bahwa evaluasi yang dijalankan dengan cara ini tidak berhubungan dengan kekayaan daerah sekitar, dengan teknik-teknik perikanan dan tingkat penangkapan ikan secara komersial, sama halnya dengan hasil-hasil perikanan eksperimental. Dengan sistem Ines-Movies, penayangan ulang data-data kasar memungkinkan pengaturan yang lebih baik terhadap ambang dalam mengevaluasi target, dengan memperhitungkan pemantulan gema pada lingkungan sekitarnya.
KATA KUNCI : akustik, perikanan pelagis, Laut Jawa, konversi berat, biomas.

The acoustic detection is extensively utilized for the study of pelagic populations. The tool, in itself, allows accurate and non disturbing observations, even if the ship can generate some behavioural reactions of the fish in its close surroundings. The method is thus utilized to delimit the zones of fish abundance, their distribution and their changes at various levels of time and space. The tool can also be employed to observe their behaviour.

Using the same instrumental adjustments and the same operating methods, the investigator is capable to easily obtain indexes of relative abundance and to measure accurately their variations. The conversion from relative measure to weight quantification is much more proved to be perilous. It requests an accurate calibration of the utilized equipment and the definition of a weight standard appropriate to the study. It also requires a critical appreciation of the obtained evaluations, taking into account the operating method adopted, the type of distribution and the encountered behavioural situations. At this phase, all available information, especially those provided by the experimental samplings and the rates of commercial catch, will be useful. In the recent years, improvement on the classification of targets according to their energy, as well as the possibility to analyze the data with different criteria of classification, has brought precious contribution.

During the PELFISH Project, several echo-integration surveys have been carried out, allowing to obtain not only estimations of « acoustic » density of fish populations in the Java Sea, but also information concerning the fish behaviour, and a qualitative aspect of the targets (index of reverberation, composition). The used tool is a dual beam echo-sounder (frequency 120 kHz, 3°5 of beam's half angle for echo-integration). The first analyses of data (Petit *et al.,* 1995) have allowed to propose a model of distribution and to give a level of accuracy in the relative evaluations. The adopted procedures for the conversion of those relative measures in weight and the resulting conclusions are presented here.

THE INES-MOVIES ECHO-INTEGRATION SYSTEM

The method of echo-integration is based on the proportionality existing between reverberated energy by a quantity of fishes and its density. That measure of density can be computerized per unit of surface or volume. Recently conceived by IFREMER (Diner *et al.,* 1989; Diner, 1991), the Ines-Movies system has been built around an interface, Ines, and a software, Movies, which can be translated as : « acoustic interface for digitalization and visualization, echo-integration and storage module ». The first systems of echo-integration are analogous and integrate the echoes according to time or number of sounder pulses. That new system allows the integration of energy of the echoes after digitized at a sampling frequency of 7.5 kHz, that is to say, a measure of the signal amplitude every 10 cm. The tool necessitates the use of an echo-sounder giving an analogous signal and a PC computer. It is moreover connected to a log and a GPS (Global Positioning System) which provide it with the speed of the ship and its geographical position. According to the type of employed echo-sounder, the signal input can be adjusted (attenuation). It is then processed, as illustrated in the schematic Figure 1, before integration. A threshold allows to avoid the integration of undesirable signals (such as background noises).

A programmed procedure enables the automatic follow-up of the bottom. Connected to the log, the tool will integrate the echoes on an exact distance, taking into account in the integration the instantaneous speed of the ship and the interval between the pulses. Ten consecutive layers of programmable thickness, referred to the surface, four others referred to the bottom, permit to localize the echoes.

By this way, the system will provide listing or stored files, in real time, with 4 sets of information : a coloured echogram, a file of digitized echoes (that will allow the playback), a file describing the route and the registered events, and at last, a file of echo-integration per distance unit. This latter recapitulates the time, the position and the depth, the integration per distance and per volume, the number of analyzed samplings and those containing a value higher than the threshold, and at last, the number of pulses concerned.

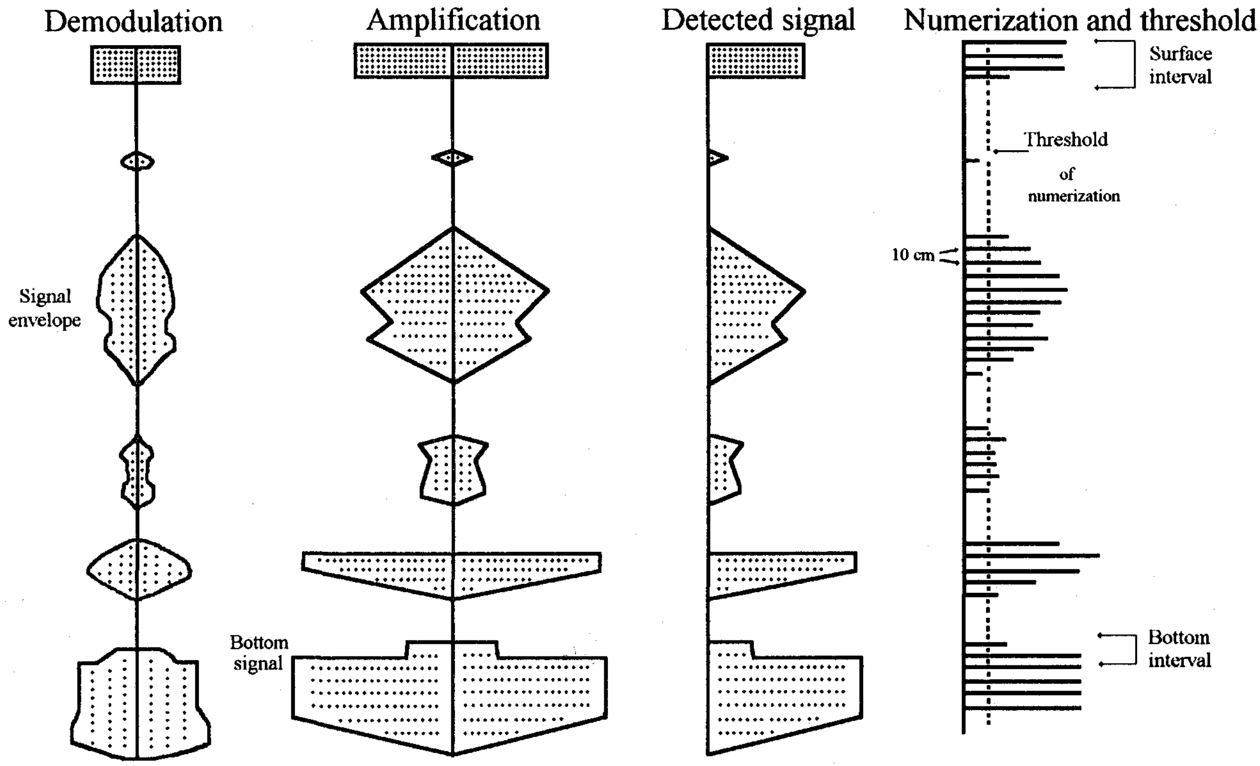

Figure 1 **Schematics of the signal processed by Ines-Movies before squaring and integration.**

Gambar 1 **Skema proses sinyal oleh Ines-Movies sebelum pengkwadratan dan integrasi.**

INTEGRATION OF ECHOES. FORMULATION

The integration takes place during a programmed distance (1/10 mile minimum) and the result is given per distance and per volume. During the PELFISH surveys, the measures of density per distance were used. For one layer, the echo-integration is calculated according to the relation below :

$$Qd = \frac{FK}{G^2} \sum_{j=1}^{n} d_j \sum_{i=1}^{m} U_{ij}^2$$

Qd = mean integration for echoes higher than the threshold, along 1 nautical mile

F = setting factor to process Qd values without decimal

K = equivalent to a hard gain

d_j = distance between the ping j and j+1, in meter

n = number of pings during 1 mile

m = number of i elementary samples during the j ping

U_{ij} = echo voltage (>threshold) for the j pulse and the i elementary sample, multiplied by the soft gain G

The gain G is introduced to amplify the received signal and allows by this way the good functioning of the automatic bottom detection.

Weill *et al.*, (1993) brought a supplementary accuracy on the coefficient K and d_j :

$$K = \frac{\text{hard gain}^1}{1852\eta}$$

where η is the number of elementary samples by meter, so $\eta = 10$.

And, for d_j :

$$d_j = S_j T_j$$

where :

S_j = speed of the ship in meter per second between two transmissions

T_j = period of transmission in second.

The coefficient d_j is introduced to take into account the variations of speed during the prospecting. In fact, a same voltage U_{ij}, obtained at low or high speed, does not represent the same quantity of energy by unit of distance. This coefficient allows then an adjustment of the voltage according to the actual covered distance.

Finally, the value Qd is a relative measurement of the abundance, proportional to the sum of voltage squared during a distance, within the thickness of the integrated water column.

CONVERSION IN WEIGHT

Principle

The obtained integration values can be directly used as an index of abundance and allow the spatial analysis of the distributions as well as the one of seasonal variations. These values remain comparable ones to the others, while they have been obtained using the same adjustments. It is not anymore the case if the acoustic characteristics of the whole sounder-transducer system change, all the more so if the settings (gains, threshold) of measurements are modified. It is the reason why people try as much as possible to use the same adjustments during consecutive surveys.

The conversion in weight of those values supposes to pass from relative to absolute references, to be free from particular conditions of measurement. Two stages are necessary for that; the first one requires to take into consideration the acoustic characteristics of the echo-sounder/integrator system in the way to convert the data in decibels[2]. The second consists to convert those last data in weight, recognizing the acoustic response chosen as "weight standard of measures".

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[1]This hard gain is usually 1,000 , or 30 dB; however, its value can be modified to adjust the amlitude signal output of the sounder with the input level of interface. Then, it has to be controlled by user.

[2]Pratically, the technique consists of deducting the instrumental constant from the data :

$$Cl\ (\text{in dB}) = -(SL+VR) + 20\ \text{Log}R + 2\alpha R - 10\ \text{Log}\frac{c\tau}{2} - 10\ \text{Log}\Psi - \text{Gains}$$

with SL = Source level; VR = Reception sensitivity; R = Maximal range of TVG; α = Absorption coefficient; c = Speed of the sound; τ = Pulse duration; Ψ = Equivalent beam angle; Gains = Gain of sounder and integrator

To define the acoustic characteristics of an echo-sounder, the biologists have developed a procedure of performance control feasible in the field. It requests the use of a standard sphere. The acoustic response of this latter has been previously measured in laboratory and the measure of its reverberated signal amplitude allows to quantify the performances of the tool.

Different methods have been described to convert the relative measures of integration in weight (Burczynski, 1982; Johannesson and Mitson, 1983). It is some questions of establishing a proportion between a number or a quantity of fish (species or a mixing of species) and its acoustic response (Midttun and Nakken, 1971). The relation can be set up directly, for example during a trawling, but the technique does not presume the possibility for the preys to avoid or escape the net. Other authors have proceeded directly the integration on precise quantities of fish in cage (the « FAO calibration method », Johannesson and Mitson, 1983); but is the behaviour of the fish confined in a cage, still normal ? Is its acoustic response not modified ? Others, at last, have obtained good results by integration and echo-counting (Marchal, 1982), but the operation supposes that the fish is well scattered, the species and its size determinated otherwise. No method seems ideal and one has to be satisfied with rare opportunities allowed by the equipment or advantageous exceptional environmental conditions. A simple method consists to use a known index of reverberation, but experiments realized on tropical species are still very few. Having a dual beam echo-sounder, 120 kHz at our disposal, we have carried out measurements of reverberation index on fish in cage (Cotel and Petit, 1996). To determine the constant of weight conversion, the average TS (Target Strength) of *D. russelli* (16 cm of fork length, about 59.6 grams of fresh weight), one of the most abundant species in the Java Sea, has been chosen : -35.45 dB/kg.

Procedure of Ines-Movies conversion

The system Ines-Movies ensures the integration of echoes by measuring the signal energy at a sampling frequency of 7.5 kHz; to take into account the performances of the tool. It was then reasonable to measure the reverberated energy, and not only the amplitude of the signal anymore, for the conversion of data. A procedure, in the menu of Movies, allows to measure automatically the energy reverberated by a sphere of reference (a tungsten ball of well-known reverberation index, here, TS = -41 dB) placed at a certain distance in the acoustic beam. That measure, which takes place according to the same procedure of a normal integration, has certainly to be realized with the same sounder adjustments as used during the prospecting. The system provides with the energy received per meter and calculates the performances of the sounder, in the field, for the distance of the target. This last value allows to verify that the given energy measurement on the sphere suits well with the echo-sounder performances which have been otherwise measured[3].

The instrumental constant, called C, including the hard gain of the integrator is given by :

$$C = \frac{1}{IE}\left[10^{\left(\frac{TSb-20Logb-10Log\Psi}{10}\right)}\right]$$

where :

I = Hard gain of the Ines interface

E = Energy by meter of the reference sphere, in squared volts

Tsb = Target strength of the standard sphere, in dB

b = Distance of the sphere, in meter

ψ = Equivalent beam angle, in dB

[3] Those performances take into account the gain of the sounder, as during the echo-integration.

Introducing the TS factor, TSf in dB/kg, the weight conversion coefficient, called Cw, for the selected target is :

$$Cw = \frac{1}{IE}\left[10^{\left(\frac{TSb - 20Logb - 10Log\Psi - TSf + 35.35}{10}\right)}\right]$$

The coefficient 35.35 $\left(\text{or } \frac{10\text{Log}(1852)^2}{1000}\right)$ allows to express Cw in tons by squared mile.

During the experiment, the sphere of tungsten, situated at 7.5 m from the transducer, has given an energy of 351948 E-07 V^2/m, so the conversion factor is :

Cw = 57 tons/nautical mile^2

However, during the surveys, the value of the F factor (equation 1) was 1000. So, the weight conversion factor must be divided by 1000 and becomes :

Cw = 0.057 ton/nautical mile^2

CONCLUSION

Thanks to the rigorous control of the apparatus and to the experiments in cage, it is possible to define a coefficient of weight conversion for our density measurements. It still remains to analyze the confidence to bring to its use and the consequences which result in its application to the relative measures of density realized in the Java Sea.

The definition of the weight conversion factor depends on the accurate knowledge of the standard target reverberation index. In fact, the control of acoustic equipment such as the echo-integrator, according to the experiment, are operations relatively easy, at least in laboratory. The accurate determination of the reverberation index of a given species is much more difficult. For the calculation, an index of average reverberation has been selected, the measures of density by echo-integration being also of average. It is true that during the experiments, the dispersion of values was relatively high. Johannesson (1984), by experimenting on close species[4] evaluated the acoustic response at -45 dB for a length of 13.6 cm, thus a value clearly higher than ours. Other experiments, associating the measure of TS and integration, which were not feasible with our equipment, could allow to sweep out the uncertainty.

As previously indicated, all the acoustical energy returning to the transducer does not represent the one which is reverberated only by targeted species. A part of it is produced by particles, plankton, larvae... Another fraction of that "background noise" can be generated by the electronic apparatus itself and the surrounding noises. It is the reason why the received signal has to be filtered using a threshold, under which signals are not taken into account. Its level is adjusted by observation of the signal on oscilloscope. There, the emergence of individual target signals appears clearly enough from the background noise. During the surveys, the threshold has been adjusted to 42, then 33 mV_{RMS} since December 1992; it has been measured in diurnal phase. Those thresholds can appear relatively low, but the recent implementations in electronics have certainly improved the quality of the reception. At 30 metres depth, where, in average, begins the maximum of detection, the adopted thresholds allow the detection of individual targets of -57 to -60 dB. By supposing a proportionality between the fish length and its reverberation index, those values would correspond to fishes of 4 to 10 cm length. The diurnal

[4]Johannesson cites *Decapterus* but does not specify the species; the experiment took place in Pulau Sanger, in the north-east of Sulawesi. The value, at 120 kHz, is calculated by echo-integration on fish in cage.

adjustment of a low threshold, which can be justified by the scattering of the targets and the ambient poorness can become a relative handicap by night if the global reverberating level of the ambient changes by the rising of a fauna, better detected. The insonified volume increasing with the depth, the targets, even low reverberating, are not anymore individual, decreasing particularly the selective effect of threshold. It seems that in the Java Sea, at least in some season, the effect is particularly more remarkable when nurseries are met, forming considerable aggregations. They have been encountered in the western and in the eastern part of the Java Sea and an observation with an underwater camera during light attraction has revealed the abundance of juveniles.

Using the weight conversion factor calculated, the evaluations of detected density during the surveys of October 1993 and February 1994 cannot be compared with the potentialities of the environment, the fishing techniques used and the rates of catch. The experimental fishing operations, even supposing avoidance, also do not confirm that overabundance. In the same sense, the TS measurements, during the different surveys show well an important proportion of targets clearly less reverberating than the average value used in the conversion factor. If then, the density measurements obtained, which represent a « biomass » measurements, are in discrepancy with those which could have been expected from the target species only. The reason is that the analysis criterion of collected information has to be adapted to the particular environmental conditions.

The system Ines-Movies that has been chosen to realize the echo-integration consists of procedures, in this case very precious, which can allow to playback the rough data. Different thresholds have been tested and finally, according to the spectrum of the echo amplitudes and the sensibility of available adjustment, the choice of the latter is very limited[5]. For the data collection, thresholds of 33 or 42 mV have been chosen. A threshold of 46 mV does not modify much the values but a threshold of 78 mV tends to eliminate severely the individual echoes, the aggregations only remain.

Finally a threshold of 62 mV_{RMS} was adopted, which, taking into account the value of the TS target (-47.7 dB), corresponds approximately to the echo of an individual fish at 20 metres depth. The surveys of October 1993 and February 1994 have been played back in laboratory with that new threshold. The synthetic result is presented in Table 1, in regard to the values measured previously with the prospecting threshold (33 mV). For that, the Java Sea is divided into three strata, using the model of stratification elaborated during the Workshop Akustikan I (Petit *et al.,* 1995), but by modifying slightly the geographical limit of the strata :

- the C zone, in the East of Longitude 113° E; its limitation in the East 114° E seems restrictive, regarding the extent of the area the most visited by big seiners, and the penetration of oceanic water in dry season.
- the B zone, in the West of 113° E.
- the A zone, in the South of Latitude 6° S. Originally, the northern limit of the zone was badly defined, due to the lack of data. This adopted limit is not ideal, because it includes, within the A zone, towards the East great depths while it seems that the bathymetry has some influence on the abundance, at least in wet season. But the zone thus defined corresponds enough to the range of about 30 miles where operate small and medium seiners.

The general tendencies, emerging from the results, lead to interesting findings. In October, which is a rich period, the raise of the threshold does not reduce the relative increase of nocturnal biomasses, even though we estimated that the latter could be principally due to the nocturnal rising of the small size target : the day-night ratios are stronger. There are two possible interpretations : the semipelagic nocturnal fauna filtered by the new threshold represents well the fauna, which is the object of evaluation. It is also possible that the effect of threshold is still insufficient regarding the low scattering of smaller

[5]The precision of adjustment could be sensibly improved by raising the programmed gain at 5 instead of 4 as during the surveys, while using the same threshold. This would allow, at the playback, to enlarge markedly the accuracy of the threshold, providing that it does not lead to saturation on the schools, which is less probable.

targets, and, in this case, the separation between the two bulks of biomass would be almost impossible to discriminate.

Table 1 Relative densities per nautic mile, using 2 different thresholds (33 or 62 mV) and biomass (threshold : 62 mV), for the three zones of the Java Sea : zone A = Lat. 6°S; zone B = Long. 113°E; zone C = Long. 113°E (N/D Ratio : Night/day relative density ratio; 62/33, D. Ratio : Ratio of relative density at 62 and 33 mV threshold; B : biomass, in tons/mile^2 weight conversion coefficient : 0.057 ton/squared mile).

Tabel 1 Kepadatan relatif per mil, menggunakan 2 batas (threshold 33 dan 62 mV) serta biomassa (threshold : 62 mV), pada tiga zona di Laut Jawa : zona A = lintang. 6°S; zona B = bujur 113°E; zone C = bujur 113°E (N/D Ratio = Rasio siang dan malam; 62/33, D. Ratio : ratio kepadatan pada threshold 62 dan 33 mV, B : biomasa, dalam ton/mil^2; koefisien konversi berat = 0.057 ton/nmil^2).

		OCTOBER 1993				FEBRUARY 1994			
		Relative Density/mile		62/33 D.		Relative Density/mile		62/33 D.	
		Thresh. 33mV	Thresh. 62mV	Ratio	B.	Thresh. 33mV	Thresh. 62mV	Ratio	B.
A	Day	593	137	23%	8	729	192	26%	11
	Night	1903	571	30%	33	1664	269	16%	15
	Total	1034	283	27%	16	1156	228	20%	13
	N/D Ratio	3.2	4.1			2.3	1.4		
B	Day	909	150	17%	9	359	72	20%	4
	Night	1736	310	18%	18	787	114	14%	6
	Total	1308	227	17%	13	573	93	16%	5
	N/D Ratio	1.9	2.1			2.2	1.6		
C	Day	1385	423	31%	24	318	152	48%	9
	Night	3815	1280	34%	72	793	264	33%	15
	Total	2682	880	33%	50	561	210	37%	12
	N/D Ratio	2.8	3.0			2.5	1.7		

Regarding to the relative proportion of density remaining after high threshold adjusting, the three zones are well individualized. The stratification originally suggested is found to be confirmed by this new processing. The remaining proportion of density after playback is more important in zone C and A and the zone B is clearly poorer. In relation to October, the results of February are not less interesting. The trends of the nycthemeral ratios between the two evaluations are reversed : in February, the increase of threshold reduces their value, what moreover goes in parallel with the general impoverishment of the environment by disappearance of a great part of semipelagic fauna in the region. The smaller proportion of biomass ratio (62/33) during the night would confirm the phenomenon. At last, the individuality of the three strata, from one season to the other, is well preserved in the proportions of biomass as well as in the level of global richness, with an impoverishment slightly more pronounced for the stratum more oceanic because from those three strata, it is the latter where the environmental conditions have been mostly modified.

The values of biomass estimated with the threshold of 62 mV and the calculated constant do not differentiate the evaluations previously realized in the region (Tab. 2).

Table 2 Some recent biomass evaluations of pelagic fish in South Asia.
Tabel 2 Beberapa perkiraan biomassa ikan pelagis di Asia Selatan.

AREA			Time	Tons/n.mile^2
Thailand	(1)	West	July 1980	15
Peninsular		East	June 1980	12
Malaysia	(1)	West	Jun-Jul 1980	19
Sumatra	(1)	North/West	August 1980	15
Sulawesi +			Oct-Dec 1980	15.4
Makassar St.	(2)			
Anambas	(3)		Jun-Jul 1981	5.5
			Nov-Dec 1982	5.4
			Jun-Jul 1983	2.9
			Nov-Dec 1983	48.8
Natuna	(3)		Jun-Jul 1981	10.6
			Nov-Dec 1982	4.4
			Jun-Jul 1983	1.2
			Nov-Dec 1983	59.3
Sangihe	(3)		Apr-May 1982	5.0
			Aug-Sep 1982	57.7
Talaud	(3)		Aug-Sep 1982	41.7
South Irian Jaya	(4)	Bintuni Area	July 1983	11.1
North Irian Jaya	(4)	135°-138° E	August 1983	4.4
East Banda Sea	(5)	128°-134° E	August 1984	5.4
			Feb-Mar 1985	1.4
Java Sea	(6)	Whole	1987	11.3
Java Sea	(7)	109°-111° E	May 1985	28

(1) results cited by Johannesson (1984)
(2) from Amin *et al.*, (1980), cited by Bailey *et al.*, (1987)
3) evaluations made by CIDA/FAO Indonesian Fisheries Development Project (Johannesson, 1984)
(4) Corindon 10, 11 cruises evaluations (Boely *et al.*, 1986)
(5) evaluations made by Amin and Nugroho (1990)
(6) estimation cited by Bailey *et al.*, (1987)
(7) Pechindon cruise evaluation (Boely *et al.*, 1987)

Those values, however, indicate the seasonal richness of the "oceanic" zone of the Java Sea, intensively exploited by the fleet of seiners, and particularly allow to measure the impact of the environmental seasonal variations to the abundance (Potier and Boely, 1990). In that region the annual deviation is of the order from 1 to 10. Those evaluations are sensible to the same bias of every evaluation using the same method. Their accuracy depends, first of all, on the gridding of sampling and from that point of view, the calculations carried out tend to show that in spite of an important spacing of the transects, the evaluations conserve a relative acceptable accuracy, thanks to a distribution rather homogeneous of the fauna (Petit *et al.*, 1995). But a considerable uncertainty still remains, in the level of reliability of adopted constant and in the proportion respectively attributable to each group of species in an environment containing a high pelagic diversity and where fishing gears enough selective (light attraction) are difficult to put to contribution for an evaluation of different specific categories. Interesting investigations would be developed in that domain of sampling, in closer cooperation with the fishing fleet.

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DISCUSSION

(Chairman Dr. MARCHAL)

Mr. MUNANDAR

Q : - How do you adjust the threshold for the surveys ? Would it be better to collect the data without any threshold and then to play back at the laboratory with different settings ?

A : - The amount of data should be so huge that it should require an enormous computer. It justifies the necessity to have a threshold.

Dr. MARCHAL comments : "You always have a threshold; the threshold is defined from the ambient noise that you do not wish to integrate. Therefore, you have to put a certain threshold level to avoid electrical noise or other disturbance."

Dr. MASSE comments : "With the INES MOVIES system, you can use, in real time, a second threshold for detection analysis. If you consider this threshold was too high as you were collecting the rough data, you can play back the data by decreasing the level of this setting for another analysis. In fact, there are 2 thresholds within the system : a low one to store the data and a second one to analyze these data."

Dr. NAINGGOLAN

Q : - Dual-Beam system has a narrow beam and a wide beam. Which beam did you use for echo-integration ?

A : - We used the narrow beam.

Dr. SIREGAR

Q : - How do you adjust the threshold before the surveys ? Must we try different values ?

A : - On survey, the oscilloscope as a part of the control equipment displays continuously the signal precisely. From this display, we can discriminate the signal due to plankton, micro organism and/or noise, from fish which is higher and gives voltage peaks; after evaluation of these undesirable signals, we adjust the threshold correctly regarding to their electrical levels. One problem still remains : if you change the threshold you started with during a survey, it becomes difficult to compare the data before and after this change.

DR. MERTA

Q : - You mentioned that the conversion factor was 0.57 tons per nautical mile, and this, for *Decapterus russelli* of 16 cm length. Since, in the Java Sea, multiple species cohabit, how can you apply this conversion factor to calculate the biomass, although *D. russelli* is one of the dominant species in the catches ?

A : - It is hazardous to apply directly any conversion factor to every density. That is the reason why we prefer using relative density instead of absolute density and its conversion problem.

Dr. MARCHAL comments : "Relative density is acoustic density or reverberation volume. From this value, you can any times change and convert biomass if you have conversion factors. You can improve your evaluation if you have more information about the fish composition and the Target Strength by species. This relative density is the basic data. To conclude, I recommend to calculate this biomass by small area and only if you have an idea about the fish composition; otherwise, it does not mean anything."

STUDY ON THE *IN SITU* TARGET STRENGTH OF FISH USING DUAL-BEAM ACOUSTIC SYSTEM IN MAKASSAR STRAIT

B.P. PASARIBU, J. LATUMETEN

ABSTRACT

An acoustic research on in situ Target Strength of fish was conducted in Makassar Strait, especially on the Kalimantan Shelf, during January and February 1995. The study focused on the following objectives : (1) to estimate the spatial distribution of fish Target Strength and (2) to compare the size distribution of fish caught by purse seine, pelagic trawl and bottom trawl with the distribution of acoustic Target Strength determined by Dual-Beam acoustic system. Data were collected along 13 transect lines in direction from Balikpapan to Matasiri Islands and vice versa. Simple random sampling technique was applied to collect fishing data. The results of the average of the fish Target Strength values were -47.02 ±4.0 dB at the night and -44.76 ±5.3 dB at the day time, and showing heterogeneity and random distribution according to distance between locations of each period. The Target Strength, obtained from acoustic data, and the two trawl data were compared to the one using Love's formula (1977). Other results were discussed.

KEYWORDS : acoustics, Target Strength, Dual-Beam, distribution, variogram, Makasar Strait.

ABSTRAK

Penelitian akustik in situ ukuran target (Target Strength) ikan di perairan Selat Makasar, khususnya di paparan Kalimantan telah dilaksanakan pada bulan Januari dan Februari 1995. Penelitian di arahkan pada dua tujuan utama yaitu : (1) perkiraan sebaran menurut ruang ukuran target ikan dan (2) membandingkan sebaran ukuran ikan hasil tangkapan pukat cincin, trawl pelagis dan trawl dasar dengan ukuran target berdasarkan sistim akustik bim ganda. Data dikumpulkan dari sejumlah 13 jalur pelayaran ulang alik dari Balikpapan hingga Pulau Matasiri. Teknik pengambilan contoh acak sederhana telah di terapkan pada pengumpulan data penangkapan. Hasil analisis memperlihatkan bahwa rata-rata besar ukuran ikan berkisar antara -47.02 ± 4.0 dB pada malam dan -44.76 ± 5.3 dB pada siang hari serta memperlihatkan heterogenitas dan sebaran teracak berdasarkan jarak antar lokasi pada masing-masing periode. Besar ukuran ikan berdasarkan data akustik dan trawl dibandingkan setelah melalui penggunaan persamaan Love (1977). Hasil penelitian lainnya juga dibahas.

KATA KUNCI : akustik, ukuran target, bim ganda, penyebaran, variogram, Selat Makasar.

Background

Fisheries acoustics is an applied methodology which is commonly used for estimating fish abundance, especially pelagic and semi-pelagic fish, in certain seawaters. The echo-integration by echo-integrator, which produces relative density, and the Target Strength are 2 important parameters that should be known in estimating fish abundance. The Target Strength measurement of fish, when estimating fish abundance, is aimed at 2 objectives, *i.e.*, to obtain the scaling factor value, which is important for computing absolute density value, and to obtain information on fish size. The Target Strength of a fish is defined as :

$$TS = 10 \text{ Log } \sigma_{bs} \quad (1)$$

where $\sigma_{bs} = (\sigma/4\pi)$ is the acoustic backscattering cross-section of fish (Burczynski *et al.*, 1990; Anonymous, 1990) as integrator scaling factor.

The extrapolation of scaling factor value, which is obtained from controlled Target Strength measurement in laboratory with conventional acoustic system using single beam transducer, has been rarely applied. The prime reason is that the fish treatment when measuring Target Strength is hardly matched with natural condition of fish, living in seawaters. Therefore, the direct *in situ* Target Strength measurement, coinciding with echo-integration during survey, is the best solution.

The Dual-Beam acoustic system, is consisted of narrow and wide beams, is an acoustic system, which is able to measure *in situ* Target Strength of individual fish in a surveyed fish population directly (Ehrenberg, 1974; Traynor and Ehrenberg, 1979).

The fish behaviour factor and marine environmental parameters that should be considered (Edwards *et al.*, 1984) are the light intensity, depth, physiological condition and behaviour among fish that influence the Target Strength value. However, the observation on the last 2 factors is difficult to perform in sea water survey area. MacLennan and Simmonds (1992) stated that, for tropical zone where the light intensity difference is only found on day period and night time, the analysis of Target Strength value should be done separately, following the two periods.

There are advantages in using the acoustical method for fish survey, such as real time data, fast data acquisition and the covering of relative large surveyed area. However, there is also limitation of this acoustical apparatus, it cannot identify fish species directly. Therefore, when conducting acoustical survey, the verification of fish species and its size is done by fishing operation during the survey. The result of fishing operation is used to predict fish size and weight from the obtained Target Strength values.

In Indonesia, the research on fish Target Strength using Dual-Beam acoustic system has been done intensively in Java Sea since 1990. This research is a collaboration between the Government of Indonesia, *i.e.*, Research Institute for Marine Fisheries, European Community Commission and ORSTOM-France. The research results show that fish Target Strength value varies, depending upon location and time period (day, night, season), with bigger values tendency toward eastern area of the Java Sea (Petit *et al.*, 1995).

Research objectives

The objectives of this acoustical research are :

- to obtain information on spatial distribution of fish Target Strength in day and night periods, at Makassar Strait,
- to compare acoustical and fishing data.

Research area and time

The research was done in the Makassar Strait, along the Kalimantan Shelf, from 1°10' to 4°40'S and 116°00' to 118°10'E, from January 26th until February 5th 1995.

Research apparatus

The acoustical apparatus, used in the research, consists of 1 set of Dual-Beam acoustic system (transducer 120 kHz with beam angles 7°/18°, echo-sounder model 102, Dual-Beam processor model 181, oscilloscope, computers and printers, including several softwares to control processors). Fishing gears consist of one pelagic trawl, equipped with a Furuno net recorder, one bottom trawl and two purse seines. One CTD (Conductivity Temperature and Depth) unit to measure sea water temperature and salinity, one GPS (Global Positioning System) unit to define research position, and other instruments such as fish size measuring boards, camera, etc. were also included. The research was conducted by using R/V Bawal Putih I, owned by the Research Institute for Marine Fisheries and based in Semarang.

Data acquisition

The acoustical data were obtained along 13 transect lines, from Balikpapan to Matasiri and vice versa. The transducer was placed on the port side of the vessel and sunk between 1-2 m from the sea surface, towed at a speed of 6-10 knots and with pulse rate of 3 per second. The acoustic signals, reflected from fish, were recorded during 10-30 minutes (along 1-3.5 nautical mile) with recording time interval of 1-3 hours. The obtained data were stored in computer disk files for later processing and analysis.

Fish species and sizes were known from the catch of pelagic trawl, bottom trawl and purse seine fishing operations. The pelagic trawl and bottom trawl gears were towed at the speed of 3.2-3.3 knots and 3.2-3.4 knots, respectively. The depths of the head rope and the ground rope of the pelagic trawl were monitored on the net recorder screen : 22-23 m and 32-33 m, respectively, therefore, the swept sea water thickness was 10-11 m. Bottom trawl was operating at 30-50 m sea water depth, with a vertical height opening of 6 m approximated. Fish data, obtained from purse seine, was the catch during night time, using light and *rumpon* (fish aggregating device). Fish size data, collected from those three gears, were carried out randomly.

Oceanographical data, which consist of temperature and salinity, were measured at 15 stations along transect lines. The sea water depth, when measuring temperature and salinity, was automatically recorded. The positions of these locations are shown in Figure 1. This figure indicates clearly the acoustic stations, the fishing stations and the oceanographic stations.

The position and time, when collecting data, were obtained from a satellite GPS receiver which was connected to the computer directly. Sea water depths were monitored and recorded directly on the computers. Then, all were matched with the observation of echogram, by using ESP software or computed average of values, from acoustical raw data, by using ESPTS and SPSS (a statistical program) program softwares in the laboratory of Bogor Institute of Agronomy (IPB). Fish species and oceanographical data were each identified and processed in the laboratory of Research Institute for Marine Fisheries.

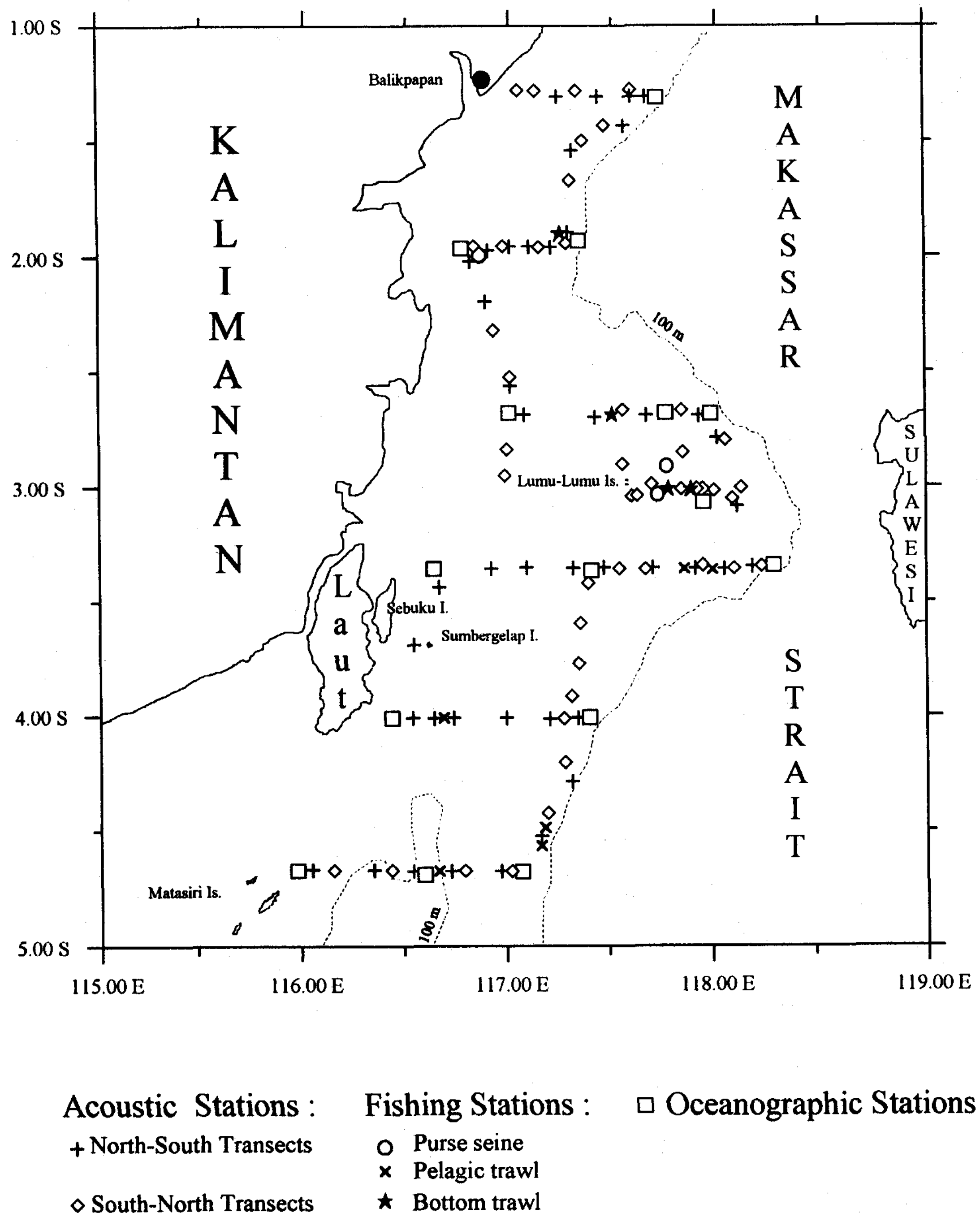

Figure 1 **Transects of the acoustical survey and position of the oceanographic stations.**

Gambar 1 **Jalur pelayaran akustik dan posisi stasion oseanografi.**

Acoustical data processing

Verification of basic acoustical data is done on the parameter distribution such as transmitting pings, echo voltage and pulse duration, received on each channel, resulting single fish Target Strength. Fish target data, located on acoustic axis of the transducer, is processed with ESPTS program following depth stratification. Strata of 10 m thickness (depth) started from 2 m below the transducer, *i.e.,* 3-4 m under the sea water surface, until 1-1.5 m above the sea bed. For each echo, Target Strength, named TS, in deciBels (dB), is computed (Anonymous, 1991) as follows :

$$TS = 20 \text{ Log } V_n - SL - GT - 2BP \quad (2)$$

where :

- V_n = Narrow-beam peak voltage after multiplication by the narrow beam correction factor
- SL = Source Level
- GT = Narrow beam receiver sensitivity and receiver static gain
- BP = Δw (20 Log V_n-20 Log V_w), the beam pattern factor
- Δ_w = Wide-beam dropoff; corrects for decrease in wide beam directivity
- V_w = Wide-beam peak voltage after multiplication by the wide beam correction factor

The averages of Target Strength values of fish, obtained from each depth stratum and for all sea water columns, were tabulated to time (night and day), detection location, and sea water depth.

Data analysis

The fish Target Strength values were set up, based on average values. Variation of horizontal spatial distribution of average (average of mean) Target Strength values was analyzed by EVA (Estimation VAriance) program, based on plot of covariance against distance. Vertical distribution of Target Strength values is known from distribution graphics of inter stratum on axis cross following sea water depth category where the data were measured.

The oceanographical parameters, such as sea water temperature, salinity and depth, were measured and tabulated. These data were plotted to stratified sea water column and the data were used to describe vertical distribution of fish Target Strength by spread plotting (scattergram) and computation of determination coefficients. The Target Strength values, used in this case, are only derived from recording locations nearest oceanographic stations.

Comparison of acoustical data and fishing data was done depending upon the kind of fishing gear as fish catch source. The fork length of caught fish was converted into Target Strength value (dB) by using empirical formulas (Love, 1971 & 1977), *i.e.* formulas for the Target Strength from fish dorsal aspects (TS_D) :

$$TS_D = 19.1 \text{ Log } L - 0.9 \text{ Log } F - 62.0 \quad (3)$$

with : L = fork length in cm

F = frequency in kHz.

and the average Target Strength from dorsal aspects with tilt angle -45° to +45° (TS_{45}) :

$$TS_{45} = 18.4 \text{ Log } L - 1.6 \text{ Log } F - 61.6 \quad (4)$$

Comparison with purse seine fishing data was done by taking Target Strength data obtained from all sea water columns. For pelagic trawl and bottom trawl fishing data, the acoustical data were taken from 22-33 m sea water column and 5-6 m above the sea bed, respectively. Finally, the Dual-Beam acoustical data and fishing data were compared and analyzed with two-way Z-test on significant level of 90% ($Z_{0.05} = 1.96$).

RESULT AND DISCUSSION

3.1 Spatial distribution of fish Target Strength

The average of fish Target Strength value obtained at day time is -47.02 dB, with a variation of 2.77 dB, and a variation coefficient of 3.54%. During night time, the average of fish Target Strength value is -44.76 dB, with a variation of 2.18 dB, and a variation coefficient of 3.30%. These results indicate that the Target Strength value at night time is higher than at day time, but the variation of spatial distribution of Target Strength values at both day and night times tends to similarity. Spatial distribution and variograms, shown on Figure 2a and 2b, show heterogeneity and random distribution based on distance (cannot be modeled), that means there is no certain structure for certain distance. This phenomenon can be interpreted as fish size difference at various locations.

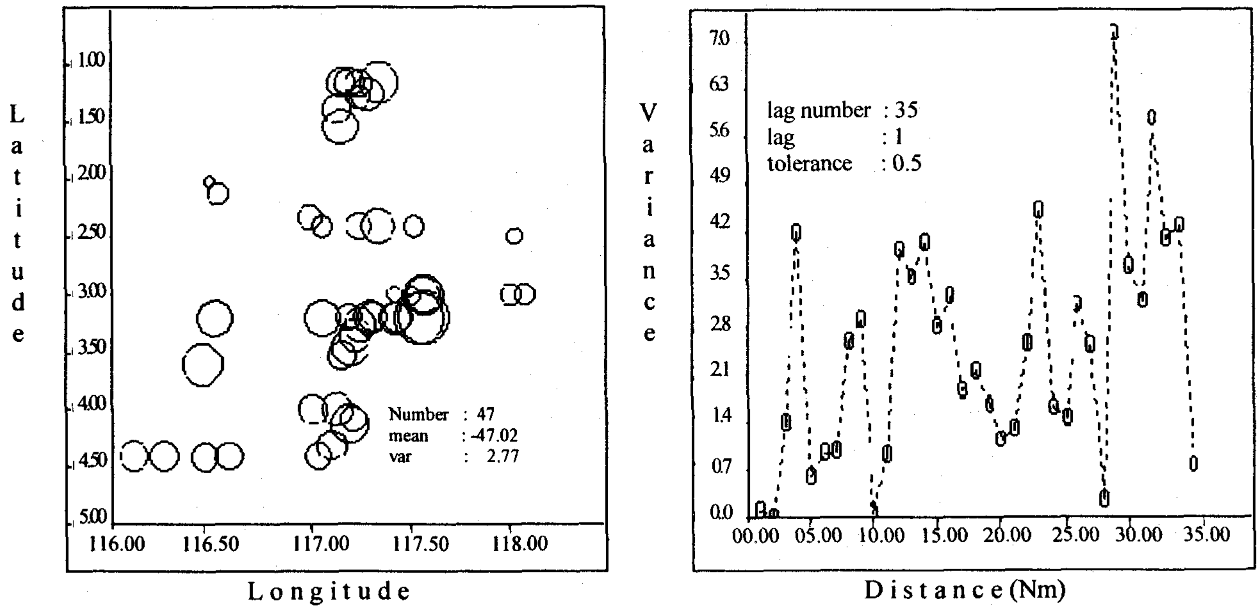

Figure 2a Spatial distribution and variogram of fish Target Strength on day time.
Gambar 2a Penyebaran spasial dan variogram ukuran target ikan pada siang hari.

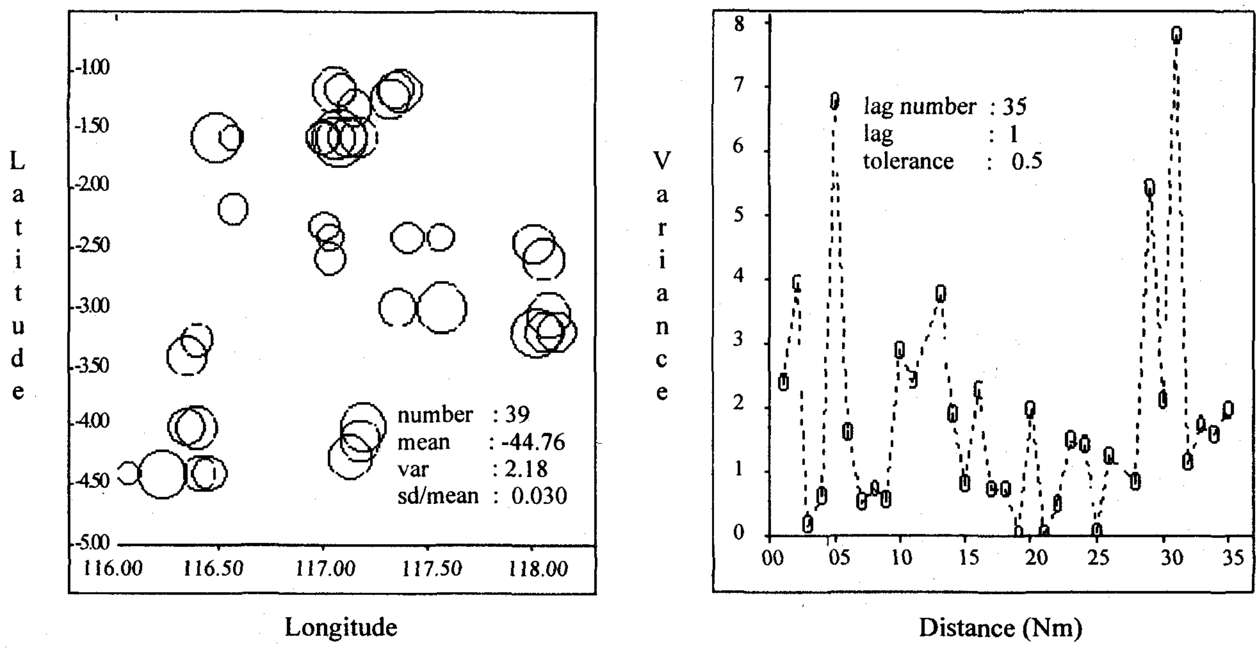

Figure 2b Spatial distribution and variogram of fish target Strength in the night.
Gambar 2b Penyebaran spasial dan variogram ukuran target ikan pada malam hari.

The difference of Target Strength value spatially, at night and day times, can be presented as vertical distribution pattern at the locations and different sea water depth as shown in Figure 3.

This vertical distribution indicates that a clear difference is found at depth stratum, close to the bottom, and mid-depth stratum. The Target Strength difference, near the sea bottom, has relation with diurnal migration activities of demersal fish which, at day time, are near the sea bed, in a "shadow" zone which cannot be detected clearly by acoustic system. At night time, the fishes move from this shadow zone and they can be detected (Freon *et al.*, 1993). The Target Strength value, which is higher at this stratum during night, shows that the larger fishes, at day time, are in the shadow zone, but at night time, fishes move from shadow zone to detectable area within the transducer beam.

Significant difference of fish Target Strength is also found at mid-depth stratum, especially at 85-105 m depth. Besides fish size, the higher Target Strength value, near the sea bottom and mid-depth at night time, can also be influenced by other factors, such as a swimbladder volume increase and a low variation level of fish orientation angles toward the transducer (Olsen, 1990).

Determination coefficients on spread plotting between Target Strength value and temperature, salinity and sea water depth stratum are analyzed partially. The contribution of those 3 factors on vertical distribution on Target Strength value is 19.87%, 12.61% and 61.00% for temperature, salinity and depth of stratum respectively. This condition indicates that distribution of fish size vertically is more dominated by the sea depth, where larger fish is found at greater depth. This kind of distribution structure is generally found for pelagic fish species (Laevastu and Favorite, 1988).

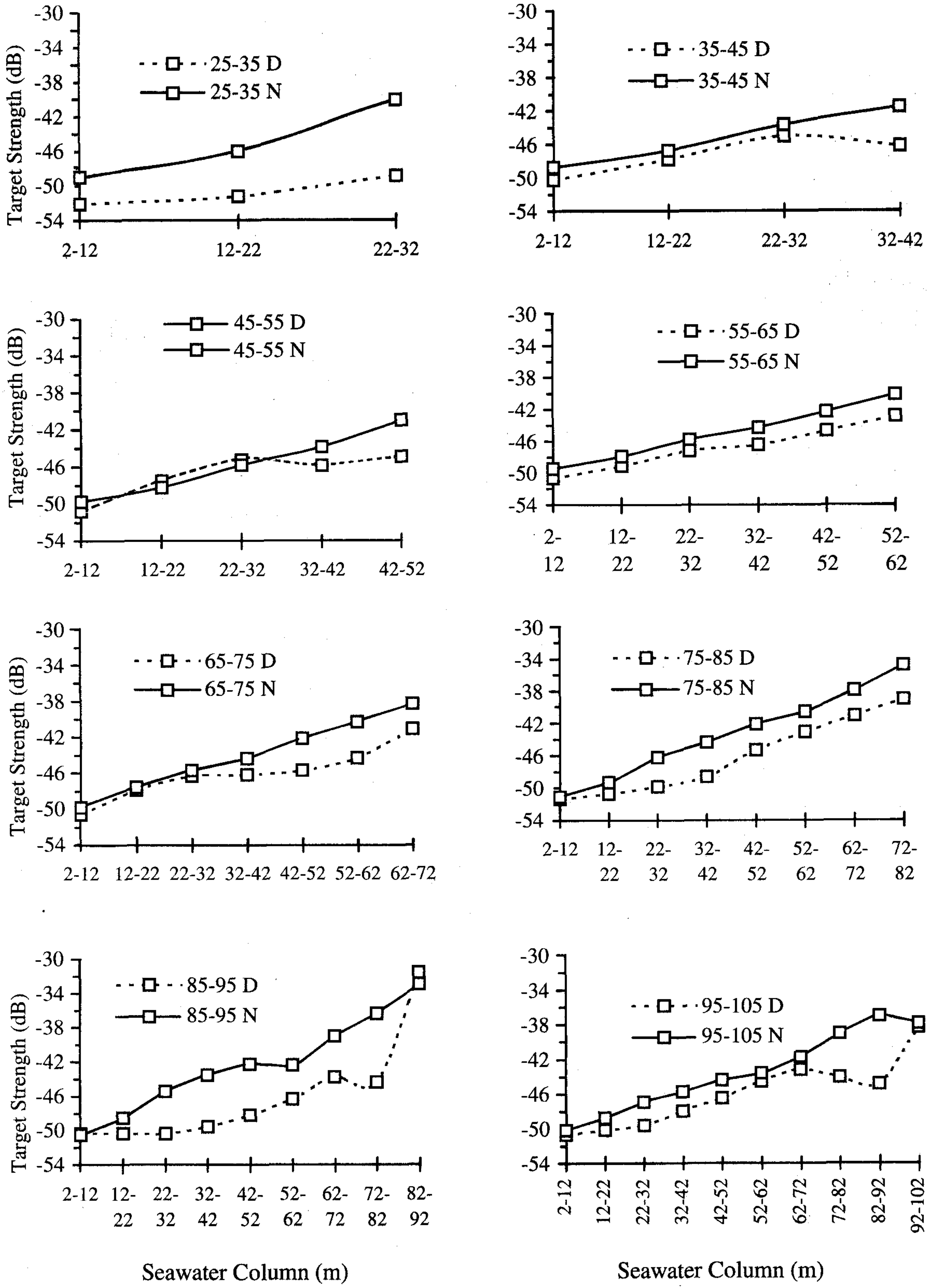

Figure 3 **Vertical distribution of fish Target Strength at locations with different depths during the day (D) and night (N).**

Gambar 3 **Sebaran tegak ukuran target ikan menurut lokasi pada kedalaman yang berbeda pada siang (D) dan malam (N) hari.**

Comparison of acoustical data with fishing data

The comparison results of acoustical data with fishing data show that there is some agreement between Target Strength values obtained from Dual-Beam data and the converted values from pelagic and bottom trawl catches, using empirical formula (Love, 1977), while converted values using the other empirical formula (Love, 1971), do not show clear agreement. Comparison results with converted Target Strength values obtained from purse seine fishing catches, using both empirical formulas, do not match.

The difference of Target Strength values obtained from Dual-Beam data and purse seine data is caused by the delay of data acquisition. In this case, the purse seine fishing data are related to fish size changes depending on the time they are near the light source. This condition indicates that trawl gear is better than purse seine for fish sampling in order to verify acoustical data, and data conversion of catch, using average tilt angle approach, is more acceptable. Table 1 presents the figures of comparison results of Target Strength values. The average fork length estimation, based on the average of fish Target Strength values as a whole, is 9.4±4.0 cm and 12.5±5.3 cm, at day and night time respectively.

Table 1 Results of Z-test at 90% level of significant (Z0.05 = 1.96) for fish Target Strength determined by Dual-Beam system and fishing data converted by using Love's formula (1971,1977).

Tabel 1 Hasil dari Z-tes pada tingkat signifikasi 90% (Z0.05 = 1.96) untuk ukuran target ikan yang ditentukan oleh sistem Dual-Beam dan data penangkapan ikan yang diperoleh dengan menggunakan rumus Love (1971, 1977).

1971

Source	Nb. of case	TS	sd	Z
Dual-Beam	338	-46.30	4.46	
Purse seine	261	-40.16	0.79	25.85
Dual-Beam	243	-43.80	3.17	
Pelagic trawl	131	-42.20	3.82	6.99
Dual-Beam	67	-43.30	6.11	
Bottom trawl	136	-39.50	10.10	12.91

1977

Source	Nb. of case	TS	sd	Z
Dual-Beam	338	-46.30	4.46	
Purse seine	261	-41.98	0.78	18.18
Dual-Beam	243	-43.80	3.17	
Pelagic trawl	131	-44.06	3.67	1.804
Dual-Beam	67	-43.30	6.11	
Bottom trawl	136	-42.63	2.48	0.86

CONCLUSION

The conclusions of this research can be written as follow :

- The fish Target Strength values in Makassar Strait have difference at day and night time. The value at the night time is bigger (-44.76 ±5.3 dB) than the day time (-47.02 ±4.0 dB), but it has the same variation with heterogeneity and randomly in horizontal distribution. The Target Strength value's difference may be caused by diurnal migration factor and environmental factor.

- The horizontal distribution pattern of Target Strength, in Makassar Strait, indicates that fish population size is different from one location to another one.
- Trawl sampling is better than purse seine sampling, and data conversion of catch, using average tilt angle approach, is more acceptable. The average fork length of fish is estimated at 9.40 ±4.0 cm and 12.5±5.3 cm, for day and night times respectively.
- The larger fish is found at greater depth stratum (70-90 m) with Target Strength values of -36.98 ±4.13 dB to -31.37 ±4.6 dB or 55.20 cm to 106.5 cm maximum fork length.

RECOMMENDATION

The research results and experiences suggest some recommendations as follow :

- Further research, using the same method, in the same location, is necessary to be carried out seasonally (West and East monsoon) and for 3 years respectively, to give more precise information on fish resources in this area.
- Besides oceanographical data, the biological data such as primary productivity, migration, etc., are needed for better understanding on fish resources distribution in this area.
- Considering wide range of fish species in tropical waters, it is encouraged to conduct Target Strength research in controlled condition for many kinds of fish species. This is useful for comparison with *in situ* data.

ACKNOWLEDGEMENT

The authors are very grateful to the Java Sea Pelagic Fishery Assessment Project (ALA/INS/87/17), *i.e.*, Dr. J. R. Durand, Dr. J. Widodo, Mr. D. Petit and Mr. P. Cotel who provided full support for this research.

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SPATIAL DISTRIBUTION OF FISH DENSITY IN RELATION TO ENVIRONMENTAL FACTORS IN MAKASSAR STRAIT WATERS

D. MANURUNG, D. SIMBOLON

ABSTRACT

The biomass or abundance of fish varies, due to environmental factors such as physical, chemical and biological. The seawater temperature and salinity as physical factors, at least, are very important when evaluating the fish density distribution.

An acoustic survey was conducted in the Makassar Strait, especially on Kalimantan Shelf during January and February 1995. The environmental data, i.e., temperature and salinity collected during the survey, were analyzed and the results are presented in this paper.

The temperature and salinity distributions indicate the presence of three water types, as coastal, transitional and oceanic water types. The fish density is in higher concentration in the Java Sea coastal waters than in the transitional and Pacific ones. The highest fish density concentration is found at the edge of coastal waters near the transitional waters area. It is considered that this situation is caused by the movement of Pacific water masses southward, to the Java Sea.

KEYWORDS : acoustic, density, pelagic fish, environment, Makassar Strait.

ABSTRAK

Perubahan besarnya biomassa atau kelimpahan ikan disebabkan oleh adanya perubahan lingkungan seperti halnya faktor-faktor fisika, kimia dan biologis. Salinitas dan suhu merupakan faktor fisika yang berperan penting dalam penentuan penyebaran ikan.

Survey akustik yang dilaksanakan di perairan Selat Makasar terutama pada paparan Kalimantan pada bulan Januari dan Februari 1995, yang didukung oleh pengumpulan data parameter lingkungan yaitu salinitas dan suhu merupakan data dasar analisis dalam tulisan ini.

Sebaran salinitas dan suhu menunjukkan adanya 3 jenis massa air, yaitu jenis kostal, transisional dan oseanik. Konsentrasi kepadatan ikan yang lebih tinggi terdapat pada massa air kostal laut Jawa dibandingkan jenis masa perairan transisional dan Pasifik. Sedangkan konsentrasi tertinggi ditemukan pada tepian perairan kostal sekitar wilayah perairan transisional. Diduga hal ini berhubungan dengan pergerakan massa air Samudra Pasifik ke arah selatan menuju Laut Jawa.

KATA KUNCI : akustik, kepadatan, penyebaran spasial, faktor lingkungan, Selat Makasar.

Background

The acoustic method for fish stock assessment has been progressed, especially during the last two decades. The advantages of this method are to give accurate results and real-time field operations. Dual-Beam acoustic system, for measuring fish target strength in situ, was first proposed by Ehrenberg (1974). Recently, the Dual-Beam acoustic system was applied for fish stock assessment in Java Sea and Makassar Strait.

It is commonly understood that the biomass or abundance of fish varies due to the environmental factors such as physical, chemical and biological (Laevastu and Hela, 1970). On the other hand, the environmental data were rarely harvested during fish stock assessment surveys, in Indonesia. Fortunately, the environmental data, *i.e.,* temperature and salinity, were taken during acoustic surveys in the Java Sea and the Makassar Strait. In this paper, the interest is focused on the relationship between physical environmental factors and fish density.

Research objectives

The research objectives are :

- to study the vertical section of temperature and salinity distribution,
- to study the relationship between physical environmental factors and fish density.

METHOD

The acoustic survey was conducted in Makassar Strait during January 26^{th} to February 5^{th}, 1995 in collaboration with the Java Sea Pelagic Fishery Assessment Project, Research Institute for Marine Fisheries. Conductivity, temperature and depth (CTD) were measured on 15 stations set up on the cruise tracks. Geographical positions of the stations and times of CTD profiles are shown in Table 1. The numbering of the stations followed the series of cruise direction from North to South (0-11), and from South to North (12-15).

Table 1 Location and time of the oceanographic stations.
Tabel 1 Lokasi dan waktu stasiun oseanografi.

No. Station	Geographical Station	Dt/Mth/Y	Local Time	Day/Night
1	00° 26 S-117° 38 E	26-01-95	19.22	Night
2	01° 56 S-117° 14 E	27-01-95	02.30	Night
3	01° 56 S-116° 48 E	27-01-95	07.14	Day
4	02° 40 S-117° 00 E	27-01-95	13.26	Day
5	02° 40 S-118° 00 E	27-01-95	21.18	Night
6	03° 20 S-118° 13 E	28-01-95	02.52	Night
7	03° 20 S-116° 40 E	28-01-95	18.53	Night
8	04° 00 S-116° 27 E	29-01-95	01.27	Night
9	04° 00 S-117° 23 E	29-01-95	11.02	Day
10	04° 40 S-117° 7 E	29-01-95	17.08	Day
11	04° 40 S-116° 00 E	30-01-95	05.47	Day
12	04° 40 S-116° 39 E	30-01-95	11.59	Day
13	03° 25 S-117° 24 E	31-01-95	11.59	Day
14	02° 56 S-117° 56 E	01-02-95	12.15	Day
15	02° 40 S-117° 46 E	03-02-95	12.00	Day

Descriptions of meridional vertical section of temperature and salinity distribution were made by lining two transactions. The first transect covered the station number of 11, 8, 7, 4, 2, 1; and the second covered the station number of 10, 9, 13, 15. These two transects were not precisely meridional, but forming the angle of about 22.5° eastward.

On the same purpose, the longitudinal vertical section was made on four transects. The station number of each transect is shown in Table 2.

The fish density was obtained by using Dual-Beam acoustic system. The fish densities, taken into consideration for analysis in relation to temperature and salinity distribution, were the fish densities detected in every stratum of one nautical mile before and after CTD stations.

The formula for calculating fish densities per unit volume (Midttun and Naken, 1971; Burczynski and Johnson, 1986), is :

$$d = M.C$$

where,

d = fish density (fish/m^3)

M = echo integrator output (V^2, Volt squared)

C = integrator scaling factor (V^2 m^3/fish)

The integrator scaling factor (C) can be calculated as following :

$$C = \sigma_{bs}.c.\pi.\tau.P_o^2.g_x^2.b_{av}^2(\phi)$$

where,

σ_{bs} = backscattering cross section (m^2/fish)

c = sound velocity in water (m/s)

τ = pulse duration (s)

P_o^2 = transmitted squared pressure at 1 m from transducer

g_x^2 = squared fixed through system gain for the equipment

$b_{av}^2(\phi)$ = mean square beam pattern factor of the transducer

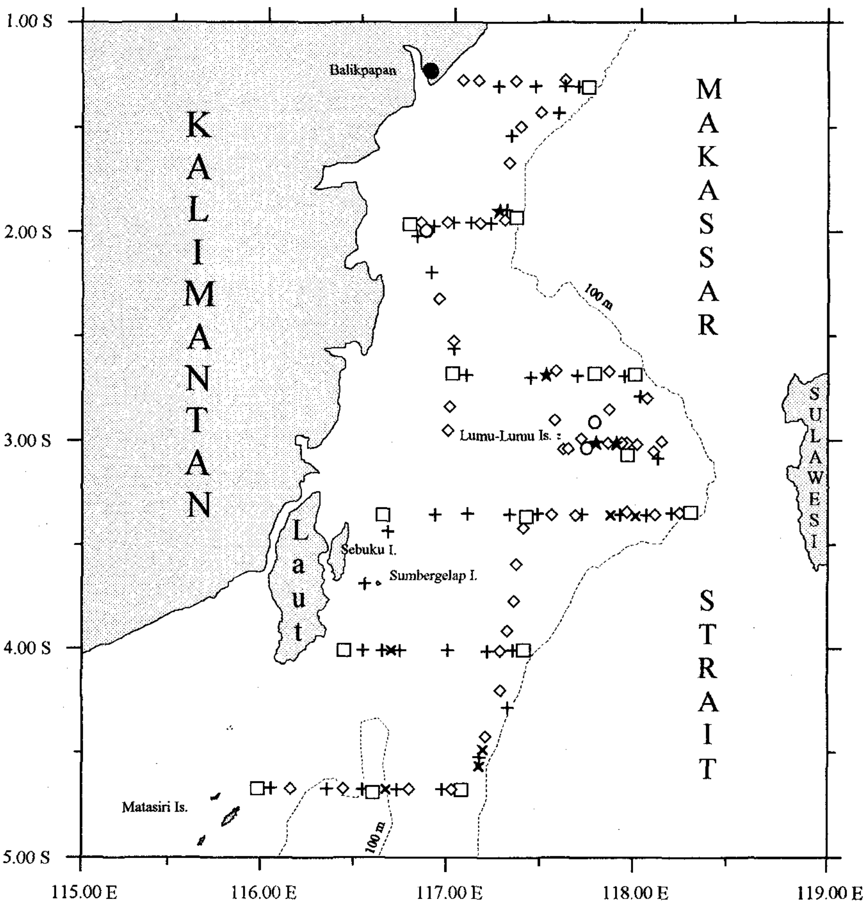
Table 2 Station number of each transect.
Tabel 2 Jumlah stasiun pada setiap jalur pelayaran.

No	Transect Code	Station No.	Number	Direction of Section
1	M-1	11, 8, 7, 4, 2, 1	6	Meridional
2	M-2	10, 9, 13, 15	4	Meridional
3	L-1	11, 12, 10	3	Longitudinal
4	L-2	8, 9	2	Longitudinal
5	L-3	7, 13, 6	3	Longitudinal
6	L-4	4, 15, 5	3	Longitudinal

Temperature and salinity distribution

The distributions of temperature and salinity along the transect M-1, are shown in Figure 1. In general, the isotherms indicate that the more southern the warmer the water is, whereas the isohalines do reversibly. The temperature range in the shallow waters of the southern part is from 28.30°C to 28.50°C, and the upper layer of the northern part is covered by temperature range from 28.10°C to 28.30°C. The temperature difference is not so big in the upper layer, only about 0.70°C.

However, there is an important phenomenon to point out that between Station 7 and 4, the isotherm lies vertically with difference of 0.40°C, or a gradient of about 0.02°C/mile, in the depth of 20 metres. The salinity distribution also indicates vertical isohalines of 32.25 to 32.50‰, with a gradient of about 0.6‰/mile. The other phenomenon is the occurrence of low salinity water, which is less than 31.50‰ up to 10 metres depth in the South.



Acoustic Stations :
+ North-South Transects
◇ South-North Transects

Fishing Stations :
o Purse seine
× Pelagic trawl
★ Bottom trawl

□ Oceanographic Stations

Figure 1 **Transects of the survey and position of the oceanographic stations.**
Gambar 1 **Jalur pelayaran survey dan posisi stasion oseanografi.**

In the northern part of the area, the temperature of layers deeper than 10 metres is less than 28.10°C. The isotherms show the development of horizontal layer and form a sharp temperature gradient which is about 0.13°C/metre in the layer near the bottom. But the salinity of the whole water column is nearly homogenous.

The vertical section of temperature and salinity of the eastern transect M-2 is illustrated in Figure 2. Considering the bathymetry, it shows that the southern part of the area is deeper than the northern part. This is in contrast to the condition on transect M-1.

The water temperature from the surface to 10 metres depth is less than 28.80°C until about 92 miles northward. The salinity range in this layer is 31.40 to 32.40‰. The isohalines, below it, tend to form horizontal stratification, emerge to the surface, and form the isohaline vertical layers with a gradient of 0.04‰ by mile at the surface, at nearly the same latitude range as the transect M-1.

Distribution pattern of temperature and salinity, along the transect L-1, are shown in Figure 3 (left side). The temperatures are nearly homogenous up to 50 metres depth. It seems that warmer water intrudes into water column with 28.80°C isotherm. The thermocline is formed at 60 metres depth in the eastern part of the area.

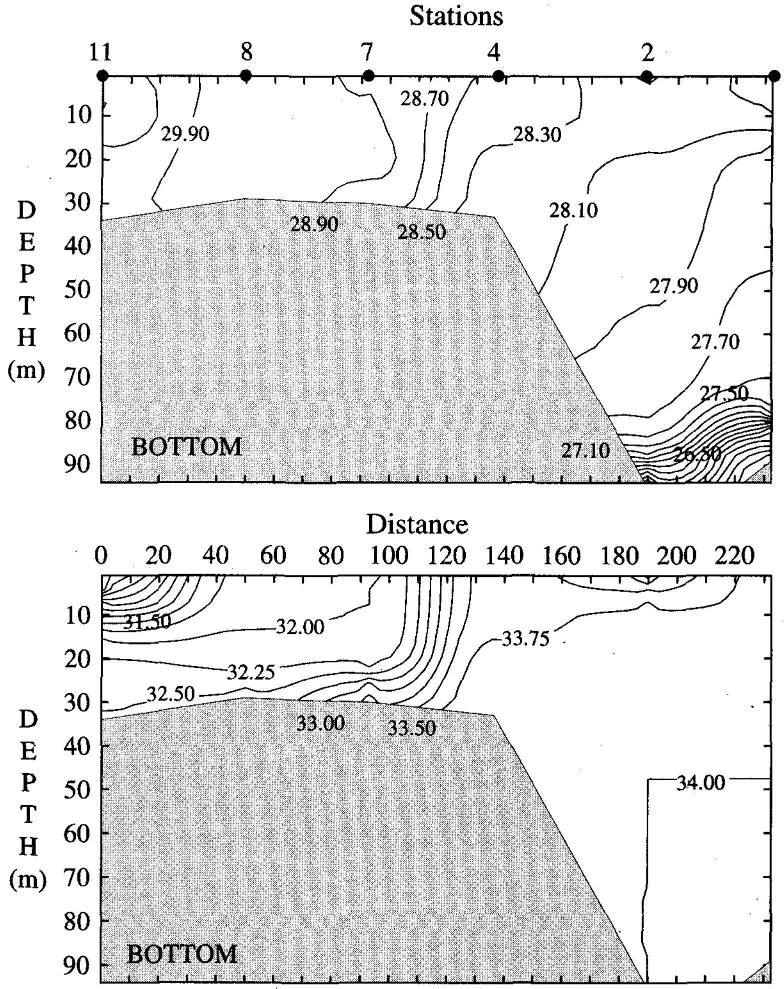


Figure 2 Meridional vertical section of temperature (upper) and salinity (lower) of M-1 transect.

Gambar 2 Penampang tegak meridional suhu (atas) dan salinitas (bawah) jalur M-1.

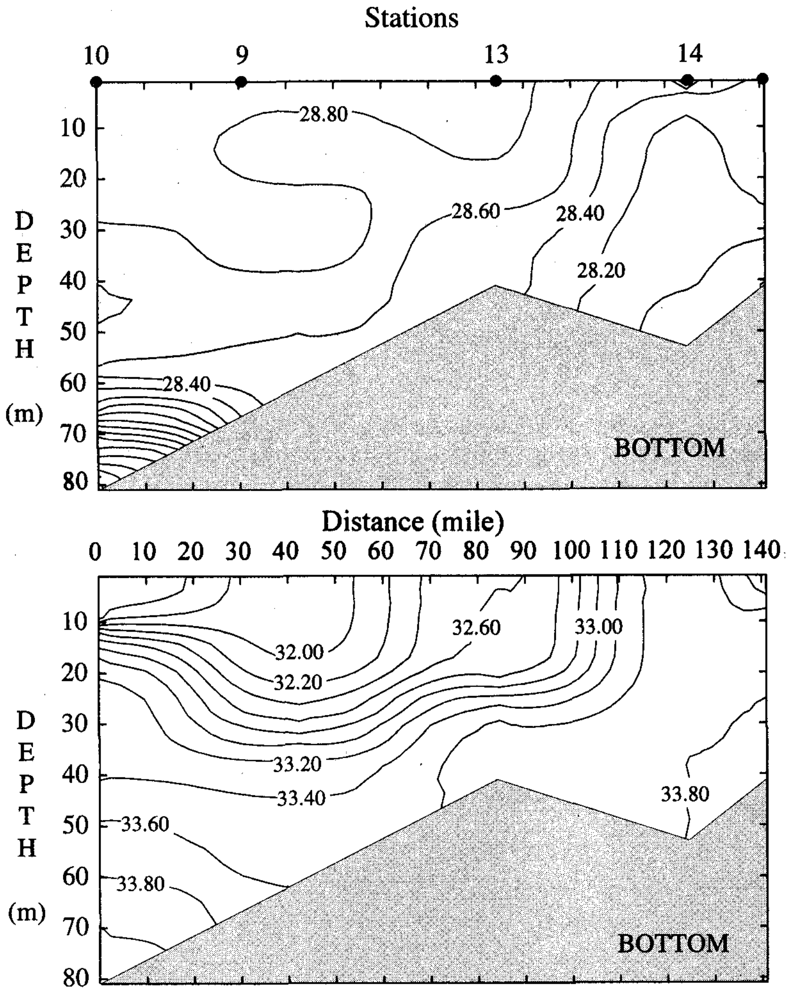


Figure 3 **Meridional vertical section of temmperature (upper) and salinity (lower) of M-2 transect.**

Gambar 3 **Penampang tegak meridional suhu (atas) dan salinitas (bawah) jalur M-2.**

The exception is seen in the water layer above 10 metres depth in the west side, where the isohalines tend to lie horizontally, especially within stratum 2 (10 to 20 metres). In this water layer, the gradient of salinity is sharp, which is about 0.10‰ per metre. In the eastern part, the isohalines of 32.50 to 33.00‰ emerge in this layer. Therefore the sharper halocline is formed.

In L-2 transect, which lies at a distance of about 44 miles to the North of L-1 (fig. 4, right), the isotherms tend to lie vertically, except in the deep layer (40-60) where they lie horizontally. Although it is not clear, it seems that a weak upwelling occurred in the eastern part of the area. This is indicated by both isohaline and isotherm formations.

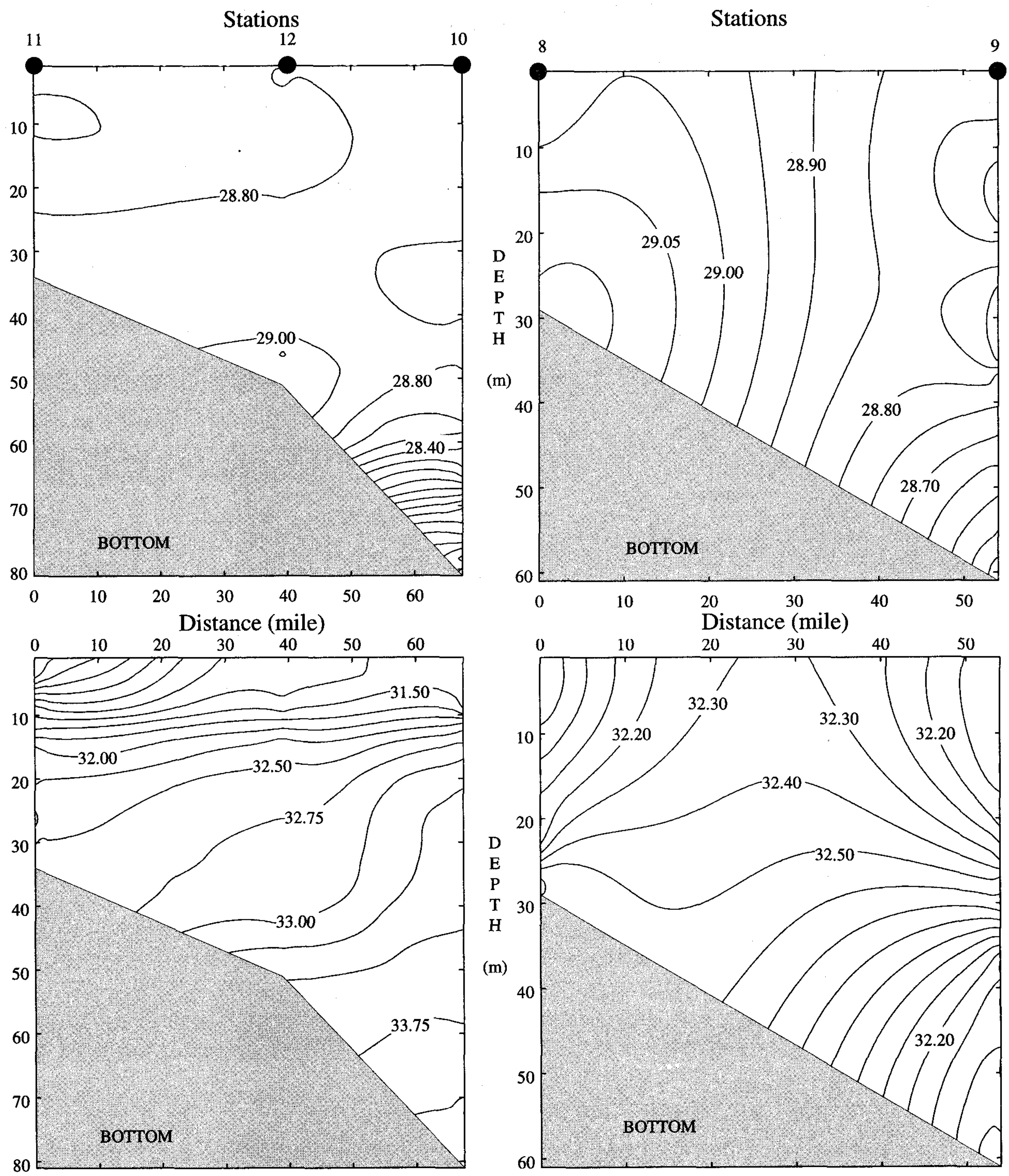


Figure 4 **Longitudinal vertical section of temperature (upper) and salinity (lower) of L-1 and L-2 (right) transects.**

Gambar 4 **Penampang tegak longitudinal suhu (atas) dan salinitas (bawah) jalur L-1 (kiri) dan L-2 (kanan).**

The distribution of the two parameters in transect L-3 is presented in Figure 5 (left). In the upper layer up to 20 metres depth, the isotherms lie vertically, where the water gradually warmer to coastal area, and also the gradient of temperature is greater. It appears that a strong gradient of salinity is formed in the coastal area, in the layer of 20 to 30 metres. This halocline is broken by the appearance of higher salinity that probably comes from the North, which can be identified with the isohalines of 33.10 to 33.50‰.

Farther to the North, the distributions of parameters are displayed on Figure 5 (right). The isotherm and isohaline patterns show that there is an intrusion of water having salinity higher than 33.85‰ and temperatures less than 28.05°C. However, this phenomenon is questionable, regarding to the time lag of data collection at Stations 4 and 5 and Station 15, which was 6 days. The environmental factors might have been changed within this time lag.

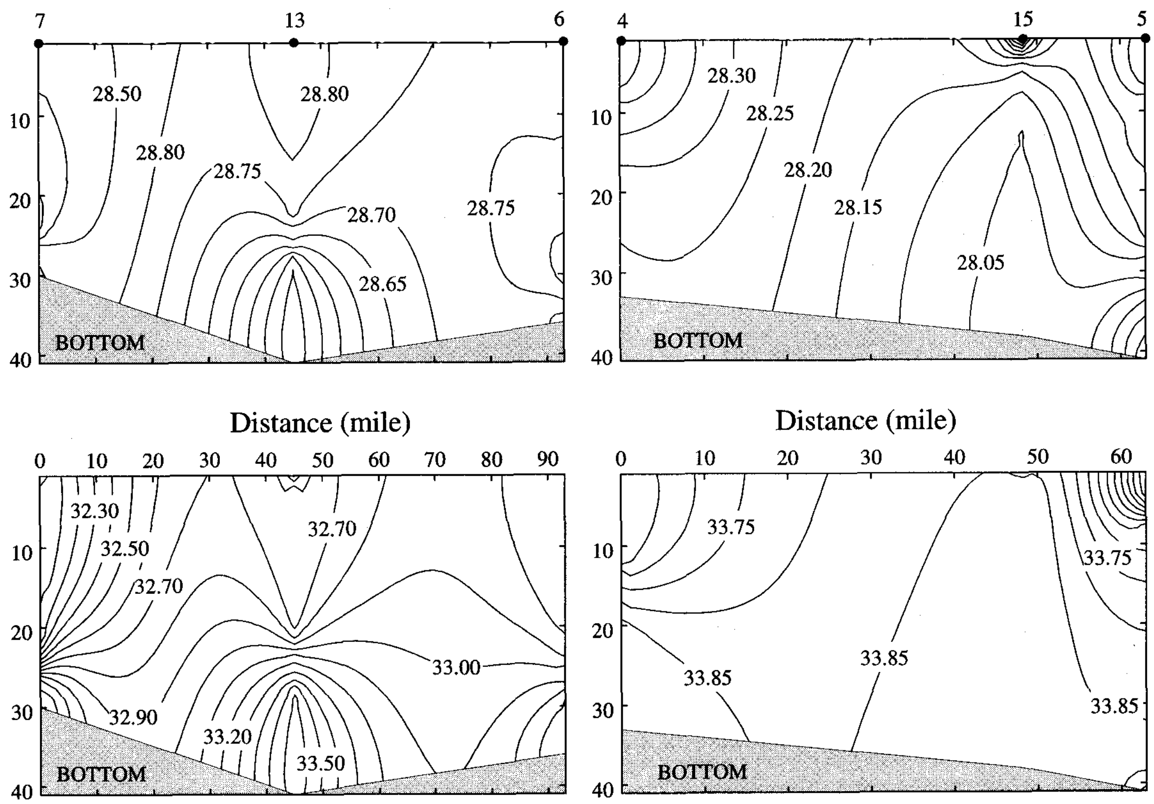


Figure 5 **Longitudinal vertical section of temperature (upper) and salinity (lower) of L-3 and L-4 (right) transects.**

Gambar 5 **Penampang tegak longitudinal suhu (atas) dan salinitas (bawah) jalur L-3 (kiri) dan L-4 (kanan).**

Spatial distribution of fish density in relation to environment factors

Along the transect M-1, fish density is much higher in coastal water type for all three upper strata (Fig. 6).

The distinctive physical property of the coastal water is a salinity less than or equal to 32.5‰ (Wyrtky,1961). The meeting of two water types, *i.e.,* the coastal water and Pacific water types around Lumu-lumu, as shown in figure 2, by the formation of water front, likely function as a border area of coastal and oceanic species. The coastal species gather in inner side of the front, especially in the layer within 12-42 m, with fish densities of 249 and 255 fish/m^3. The oceanic species, apparently not much abundant in the northern part of the survey area, except the fish in stratum-9, where the thermocline is likely formed, have a relatively high density (157 fish/m^3). The purse seine catches in leg 3, at position 01°56 E, were dominated by *Sardinella sirm* and also *Rastrelliger kanagurta* (tab. 3), which prefer more saline waters.

The fish distribution, along the eastern transect M-2, is presented in figure 7. Between two meridional transect, the water depth gradually increases in two directions (southward and eastward) as shown in Figure 2, Figure 3, and Figure 4. Therefore, the southern part of the transect M-2 is deeper than of northern part. The position of the coastal water edge shifted southward. In this transect, the halocline is narrower in the Southernmost where fish density of coastal species is higher. In the Northernmost, the oceanic species apparently disperse in the whole water column with density ranging from 34 to 89 fish/m^3.

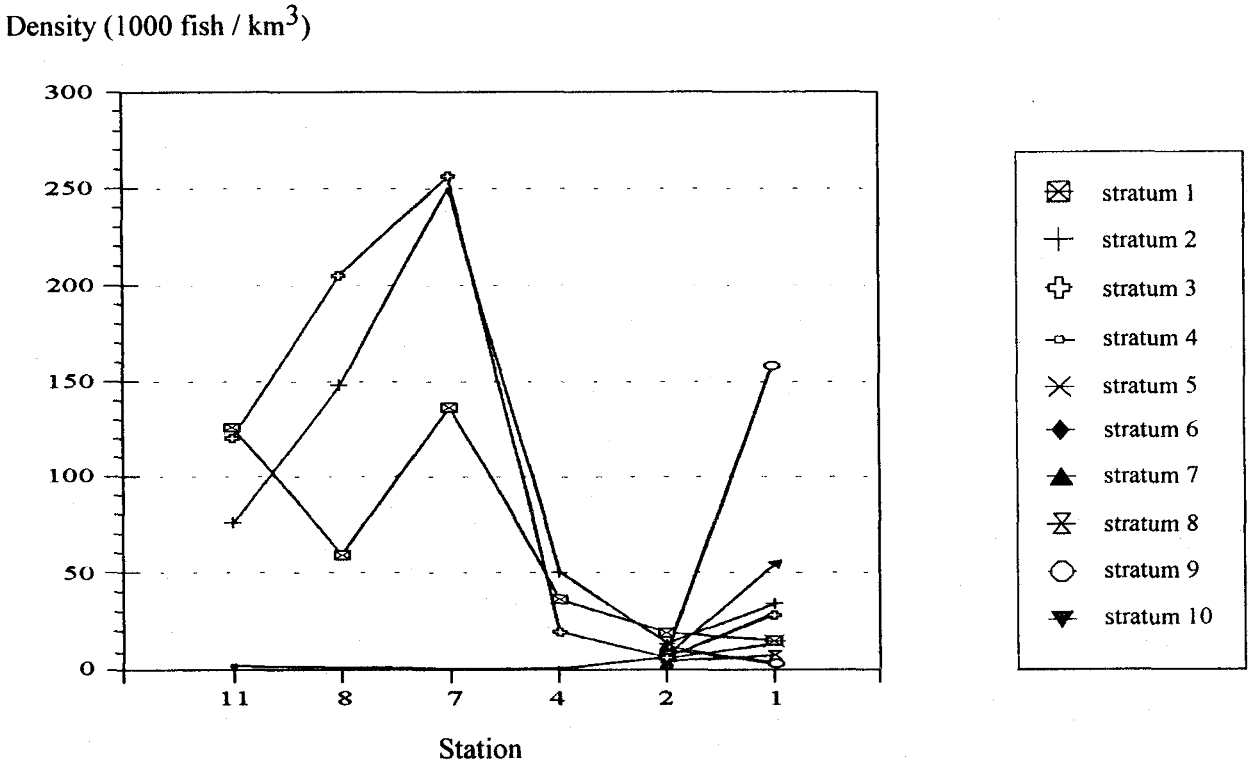


Figure 6 Meridional distribution fish density along transect M-1 in each stratum.
Gambar 6 Sebaran meridional kepadatan ikan sepanjang jalur M-1 menurut stratum.

Table 3 Position of fishing operation and catches.
Tabel 3 Posisi stasiun penangkapan dan hasil tangkapan.

No	Transect	Position	Time	Fishing gear	Local and scientific name of catch
1	Leg 3	01°56 S 116°56 E	16.00	Purse seine	Tembang siro (*Sardinella sirm*) Kembung lelaki (*Rastrelliger kanagurta*) Kembung perempuan (*R. neglectus*)
2	Leg 5	02°40 S 117°30 E	14.30	Bottom trawl	*Letrinus sp.* *Scolopsis* *Abalistes* Udang kipas Ikan sebelah
3	Leg 5	02°58 S 117°32 E	17.00	Purse seine	Layang (*Decapterus russelli*) Layang deles (*D. macrosoma*) Selar bentong (*Selar crumenophthalmus*) Tembang siro (*Sardinella sirm*) Kembung lelaki (*Rastrelliger kanagurta*)
4	Leg 5A	03°00 S 117°52 E	10.00	Bottom trawl	Tembang siro (*Sardinella sirm*) Teri (*Engraulidae*) Ikan terbang (*Exotidae*) Cumi-cumi (*Loligo sp.*) Parang-parang
5	Leg 5A	03°00 S 117°59 E	16.00	Purse seine	Layang (*Decapterus russelli*) Layang deles (*D. macrosoma*) Selar bentong (*Selar crumenophthalmus*) Tembang siro (*Sardinella sirm*) Kembung lelaki (*Rastrelliger kanagurta*)
6	Leg 7	03°20 S 117°57 E	06.30	Pelagic trawl	Layang (*Decapterus russelli*)
7	Leg 9	04°00 S 116°40 E	04.00	Pelagic trawl	Selar bentong (*Selar crumenophthalmus*) Lemuru (*Sardinella longiceps*) Cumi-cumi (*Loligo sp.*)

Note : *) Tuna and barracuda were caught by trawl line in leg 8 at 13:00.
*) Tuna, eastern little tuna and spanish mackerel were caught by trawl line in leg 8 at 9:00.

Considering the bathymetric condition, the depth in the southern part of the transect M-2 (Fig. 2) is the highest which decreases gradually northward.

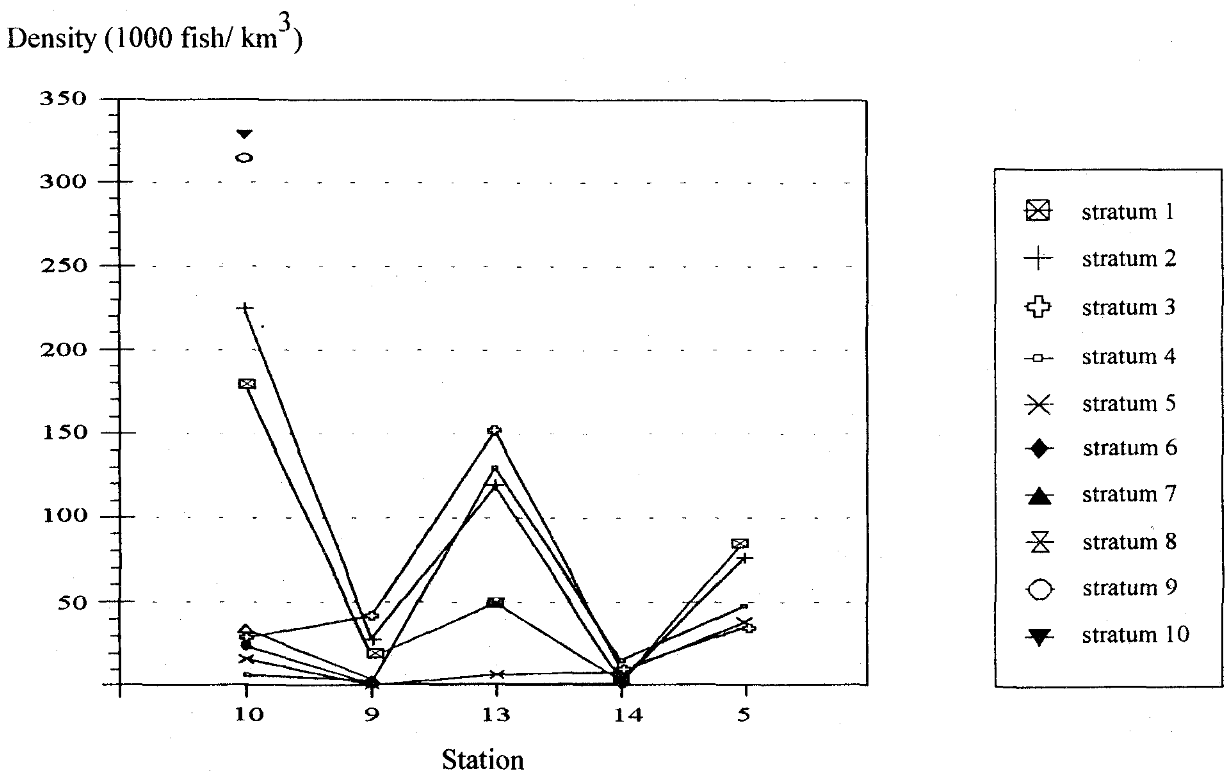


Figure 7 Meridional distribution fish density along transect M-2 in each stratum.
Gambar 7 Sebaran meridional kepadatan ikan sepanjang jalur M-2 menurut stratum.

The strata of fish density in Station 10 are ten in number, and five in Station 13 and Station 5. The occurrence of the front between Station 13 and Station 14 seemingly separates the coastal pelagic and oceanic horizontal distribution.

Around Station 13, which is located in the southern side of the front, the fishes are concentrated in the water layer within depth 12-42 m, where the salinity ranges from about 32.60 to 33.60 ppm.

The species groups occupy that salinity range apparently lesser when the isohaline of these values go deeper and wider, such as at Station 9 and concentration of (224 fish/m^3) in the stratum 2 around Station 10, where the isohaline of that range emerges to that depth level.

The occurrences of species group preferring low salinity (<32 ppm) are found in the stratum 1 of Station 10. In this area, the high concentration of another species group, in the deeper layer below the thermocline, are also found as shown by the values of fish density in stratum 9 and stratum 10.

The oceanic species concentrations are low in all strata near the front and tend to increase northward. The occurrence of these species can be indicated by catches in leg 5A, at position 03°00 S, 116°49 E as shown in table 3.

The fish densities at every station, in each stratum, describe 4 longitudinal vertical distributions and are presented in Figure 8, Figure 9, Figure 10 and Figure 11, respectively.

Considering the oceanographic distribution in transect L-1, the stratum 1 of Station 10 occupied by the species group of low salinity (<31.50 ppm), is probably different with the others. The fish density detected in stratum 2 and stratum 3 around the station can be more likely related to fish detected in stratum 1 and stratum 2 around Station 12, and stratum 1 around Station 3 as indicated by the running of isohaline 32.50 ppm. It means that fish density plotted in Figure 8, sounds differently. The species group, dense in stratum 2 of Station 12 are dispersed in stratum 2 and stratum 3 of Station 10. In the same way, we can delineate the other species group distribution due to salinity distribution.

Density (1000 fish/ km³)

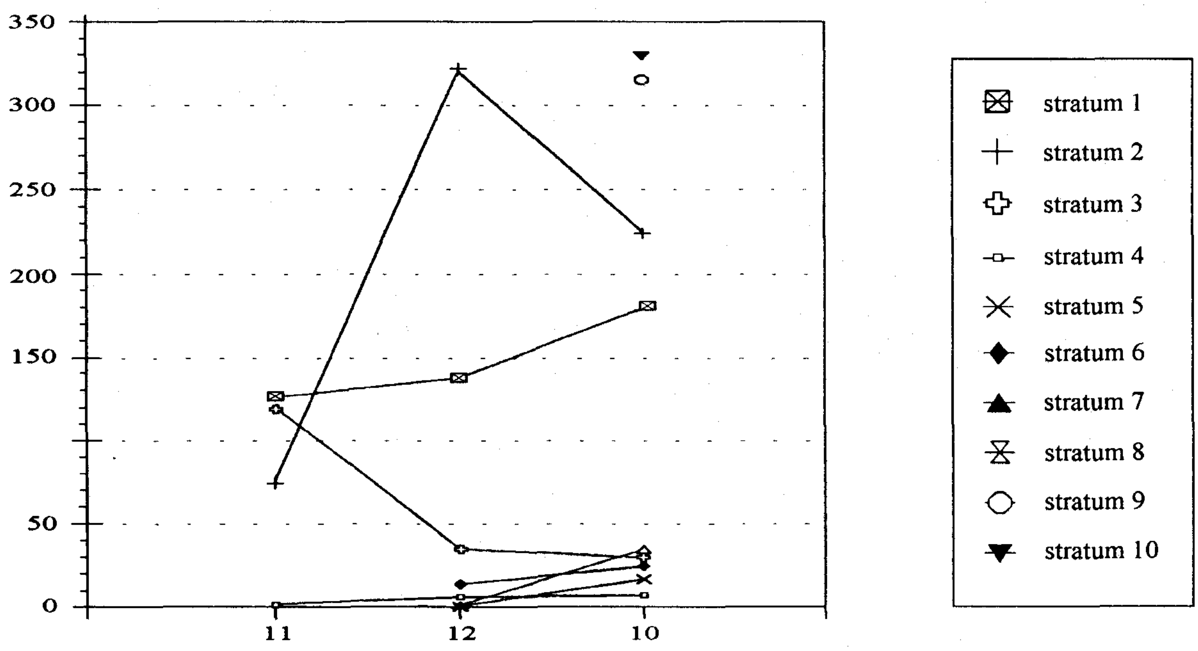


Figure 8 Longitudinal distribution fish density along transect L-1 in each stratum.
Gambar 8 Sebaran longitudinal kepadatan ikan sepanjang jalur L-1 menurut stratum.

Between Station 8 and Station 9, the isotherms tend to lie vertically, and the salinity from depth intrudes the upper layer waters and divides them into east and west low salinity (Fig. 4 night). This condition consequently separates coastal pelagic species in three strata, but the density was lower in the eastern side. The pelagic trawl operations at 03°20 S, 117°57 E obtained the catch of *D. russelli*.

Between Station 7 and Station 13 (Fig. 5), the isotherms and isohalines show the same condition with transect L-2 mentioned above, and also the fish density distribution of Station 6. The high density in stratum 3 of the Station 6 (572 fish/m^3) where the salinity ranged from about 32.80 to 33.30 ppm, belongs to oceanic species.

The fish densities distribution along transect L-3, in Figure 10, indicated a similar pattern of stratum 1 and stratum 3, with the values for all three Stations, greater in the latter. Regarding to the distribution of salinity in Figure 5, the fish detected in the western part of stratum 1 might belong to the coastal group where the salinity is less than 32.20 ppm, while the other groups preferred the salinity around 32.70 ppm, at stratum the isohaline condensed in all stations and isohaline of 32.90 ppm situated in the mid of the stratum 1. The fishes in the west part of the stratum 2 of Station 1, seem to be of the same group as in stratum 1, and also the same as in stratum 2. The increasing of the density eastward at stratum 4, is related to the thickness of the stratum near the bottom.

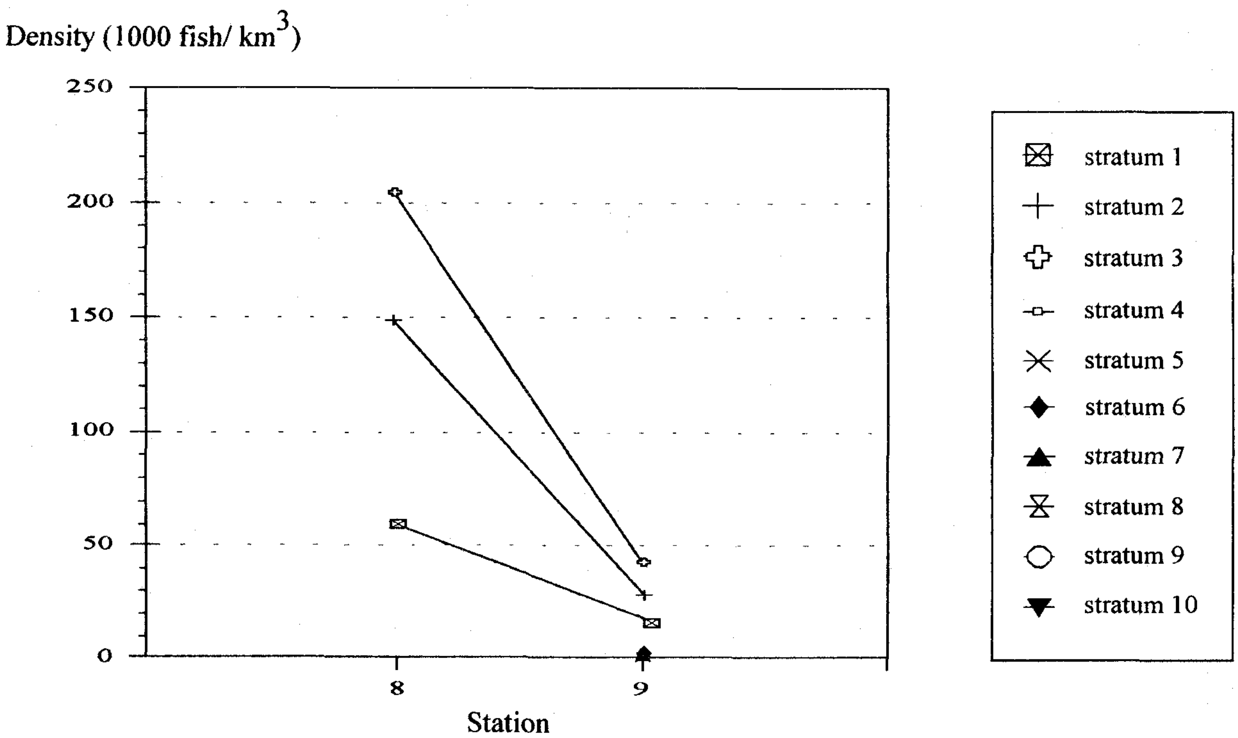


Figure 9 **Longitudinal distribution fish density along transect L-2 in each stratum.**
Gambar 9 **Sebaran longitudinal kepadatan ikan sepanjang jalur L-2 menurut stratum.**

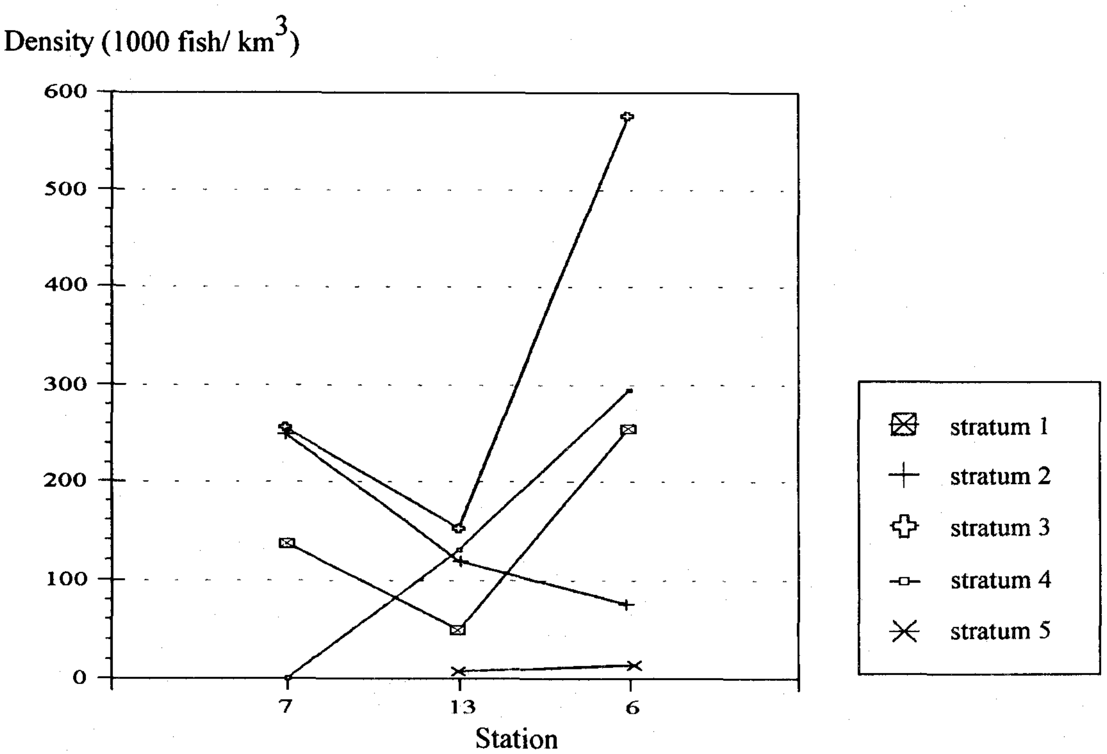


Figure 10 **Longitudinal distribution fish density along transect L-3 in each stratum.**
Gambar 10 **Sebaran longitudinal kepadatan ikan sepanjang jalur L-3 menurut stratum.**

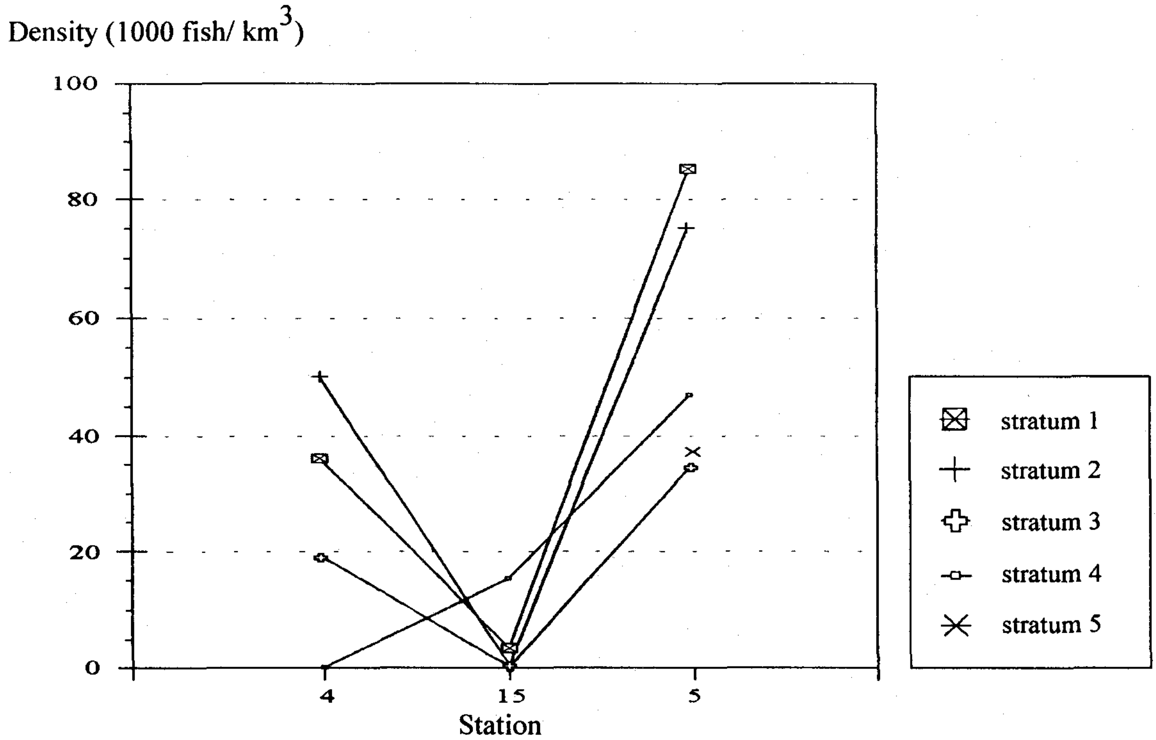


Figure 11 Longitudinal distribution fish density along transect L-4 in each stratum.
Gambar 11 Sebaran longitudinal kepadatan ikan sepanjang jalur L-4 menurut stratum.

CONCLUSION

The survey area covered two water types, *i.e.,* Java Sea water type in the south-west part and Pacific Ocean water type. The meeting place of the water type formed a front, both in temperature and salinity, and the spatial distribution of the species seems related to the salinity values.

During the survey, the coastal species, were more abundant than the oceanic species. This could be related to the season, when current velocity is low, and thus, the Java Sea waters intrude farther north.

In general, the coastal species densities are higher, close to the front, than the oceanic species ones.

ACKNOWLEDGEMENT

We thank the Java Sea Pelagic Fishery Assessment Project for their assistance and permission for using raw data.

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DISCUSSION

(Chairman Dr. WIDODO)

Dr. ILAHUDE

Q : - My question concerns Dr. Manurung but also the former speaker Mr. Sihotang. The presentations deal with only one survey, it means during one season. Will there be any other survey in deep, afterward, during the other seasons ? If we want to compare, for example, day and night data, on two stations, the confidence will be too low. There are so many seasonal environment variations that these surveys have to be repeated in the future.

A : - Repetition is not of my responsibility. It would be nice to re-survey during the four seasons. Now IPB tries to perform acoustical surveys in the Sunda Strait. Maybe these surveys could be assumed by RIMF.

Dr. NURZALI

Q : - Is there any relationship between high fish density and the vertical distribution of salinity and temperature in the water column ?

A : - Yes, I think at this station, the density of fish is higher.

Q : - From your point of view, what is the predominant factor for high density ? Is it the salinity or the temperature ? Because for tuna, the temperature is the most important one.

A : - That is why, I say that maybe it is tuna. In coastal waters, the difference of temperatures is very low, only 0.2 ° C. On the contrary, the difference of salinity, in this area, reaches 1 ‰. Thus, it is better to bring attention to the salinity distribution.

Dr. SIREGAR comments : "Just a little comment on the question of Mr. Ilahude. We all know that oceanographic research, using vessels, is very expensive. In the next presentation, I will show you how the use of satellite remote sensing can be helpful for oceanographic surveys."

PELAGIC FISH ABUNDANCE FROM SEMARANG (CENTRAL JAVA) TO SOUTH CHINA SEA IN APRIL 1993

D. PETIT, D. NUGROHO, M. POTIER

ABSTRACT

An acoustic survey, from Semarang towards the South of China Sea, allows to describe the haline situation and the distribution of abundance in pelagic fishes at the end of the wet season. At that moment, the fleet of Javanese seiners operates in the south-west of the Natuna Islands, on the depths of 50 meters. The analysis of haline vertical profiles shows the presence of three zones : the Java Sea with vertical gradients due to the coastal desalinization, Karimata Strait with isohaline water at 33.5‰ and the South of China Sea with deep water at 34‰. The last sector where the fleet was operating, was three times richer than the Javanese waters at that time. Without direct correlation with that, the zonation of the abundance (scattered or aggregated fishes) follows the zonation of salinity. The water of the strait is poorer, and the water of the Java Sea is richer while the desalinization is stronger. It seems that the richness of water is particularly related to the bathymetry by the presence of an semipelagic fauna when the bottom exceeds 30 meters. This semipelagic fauna commutes twice migration towards the surface during the night, behaviour which is more accentuated in this fishing zone than in the Java Sea. In the Karimata Strait, where the depth is less than 30 meters, the pelagic and benthic faunas are dominant. In the Java Sea a great aggregation of larva and juveniles has been detected particularly in the South of Belitung Island, that confirms the role of the basin in the reproduction of pelagic species. At that period of the year, it is the slopes of the basin which seem to be richer. These populations, thus, avoid the strong coastal desalinization but also its deeper part. All these observations do not seem to confirm the theory of Hardenberg, which assumes the existence of a migration between the South China Sea and the Java Sea.

KEYWORDS : Java Sea, South China Sea, salinity, acoustics, pelagic fish, Carangidae, abundance, shoals, distribution.

ABSTRAK

Survey akustik pada pelayaran dari Semarang menuju Laut Cina Selatan memberikan gambaran tentang keadaan salinitas dan distribusi kelimpahan ikan pelagis pada akhir musim hujan. Pada saat itu armada kapal pukat cincin yang berbasis di Jawa beroperasi di perairan sebelah tenggara Pulau Natuna dengan kedalaman sekitar 50 meter. Analisis penampang tegak salinitas sepanjang jalur pelayaran memperlihatkan adanya tiga zona yang berbeda yaitu : zona Laut Jawa dengan gradient tegak salinitas rendah yang disebabkan adanya pengenceran pantai, zona Selat Karimata dengan isohaline 33.5 ‰ dan zona Laut Cina Selatan 34 ‰. Pada zona terakhir ditemukan sejumlah armada penangkapan pukat cincin sekitar tiga kali lebih banyak dibandingkan di Laut Jawa.Tanpa pengujian langsung terhadap korelasi hal tersebut, zona kelimpahan ikan (tersebar maupun berkelompok) diduga mengikuti zona salinitas dimana kelimpahan di perairan Selat Karimata terlihat lebih rendah, tetapi di Laut Jawa lebih tinggi pada saat berlangsungnya salinitas rendah. Keadaan ini memperlihatkan bahwa kelimpahan tersebut berkaitan dengan kedalaman perairan serta munculnya kelompok jenis semi pelagis pada kedalaman lebih dari 30 meter. Kelompok tersebut melakukan dua kali ruaya tegak kearah permukaan pada saat malam hari, dimana tingkah laku lebih menonjol di daerah penangkapan di perairan Laut Cina Selatan dibandingkan di Laut Jawa. Di perairan Selat Karimata, dimana kedalaman kurang dari 30 meter kelompok jenis bentik dan semi pelagis diduga lebih mendominasi kelimpahan ikan, sedangkan di Laut Jawa keberadaan kumpulan larva dan yuwana terdeteksi terutama di perairan sebelah selatan Pulau Belitung. Keadaan ini menegaskan peranan lembah pada reproduksi jenis ikan pelagis. Pada waktu tersebut wilayah lekukan (slope)lembah nampaknya memiliki kondisi yang lebih subur bagi populasi ikan pelagis untuk menghindari dari proses desalinisasi di pantai serta perairan yang lebih dalam. Semua observasi ini tidak menampakkan ketegasan teori Hardenberg (1937) yang menghipotesakan adanya ruaya ikan layang dari Laut Cina Selatan menuju Laut Jawa.

KATA KUNCI : Laut Jawa, Laut Cina Selatan, akustik, ikan pelagis, Carangidae, kelimpahan, kelompok, distribusi.

The fleet of Javanese fishery of small pelagic of the Java Sea achieves every year a seasonal change of location according to meteorological conditions and the migration of fish. These moving have been described by Boely *et al.* (1988) and Potier and Petit (1995). Operating in the Java Sea, particularly in the East, between July and December, the fleet moves towards the Makassar Strait in the beginning of the year. In March - April, this zone is deserted and during about three months, the seiners make very long trips toward the south of China Sea (at the South of Natuna Islands) to continue the fishing. In the same way fishing sectors of the Java Sea had been explored , it was interesting to discover the fishing zones in this region to evaluate as much as possible the local abundance. It was also worthwhile to know if a continuity of populations exists between the two basins, that of the South of the China Sea and that of the Java Sea. The reason of this curiosity is that the same dominant species are captured in the two regions (*Decapterus russelli* and *D. macrosoma*).

MATERIAL AND METHODS

The acoustic survey was carried out with R/V Bawal Putih I, a stern trawler of 42 m of length, in April 1993. The measures of density per mile were obtained with a dual beam sounder of 120 kHz frequency by echo-sounding along the trip (speed of about 6 knots). The going trip was done through the East and return trip is in the West (Fig. 1). Between the two, three days were passed in the fishing zone to effectuate a rectangular night and day trip among the seiners as well as samplings with a bottom trawl or onboard of seiners.

Hydrologic fixed stations were performed every twenty miles in order to analyze the haline structure of the water mass.

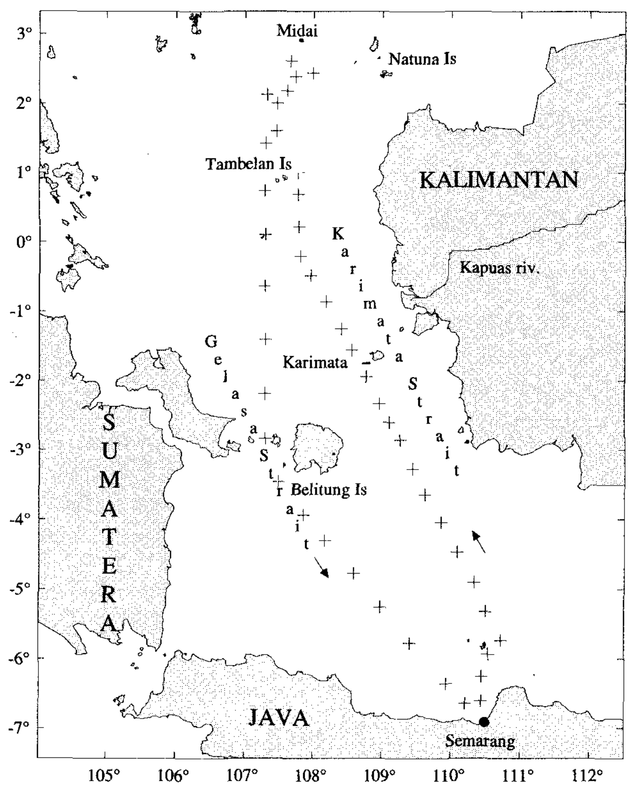

Figure 1 **April 1993. Location of salinity profiles during the acoustics survey.**
Gambar 1 **April 1993. Lokasi stasion oseanografi pada jalur survey akustik.**

Salinity

The thermal variations being low in the region and linked to alternation of day and night, temperature does not represent an important ecological parameter. On the contrary, the salinity variations, which can reach more than 4°/₀₀ during the year, are recognized to have an influence on the populations. The vertical haline average (go and back) shows the existence of 3 zones but with a very low gradient increasing from the South towards the North, of the order of 0.5°/₀₀ (Fig. 2); these 3 zones are: the Java waters lower than 33.5°/₀₀ , the waters of the strait which still pour into the Java Sea and in the utmost North, the meeting of the South China Sea waters, where the fleet operates. In the strait, although the late stage of wet season, persists a plume of desalinization in front of the Kapuas River mouth.

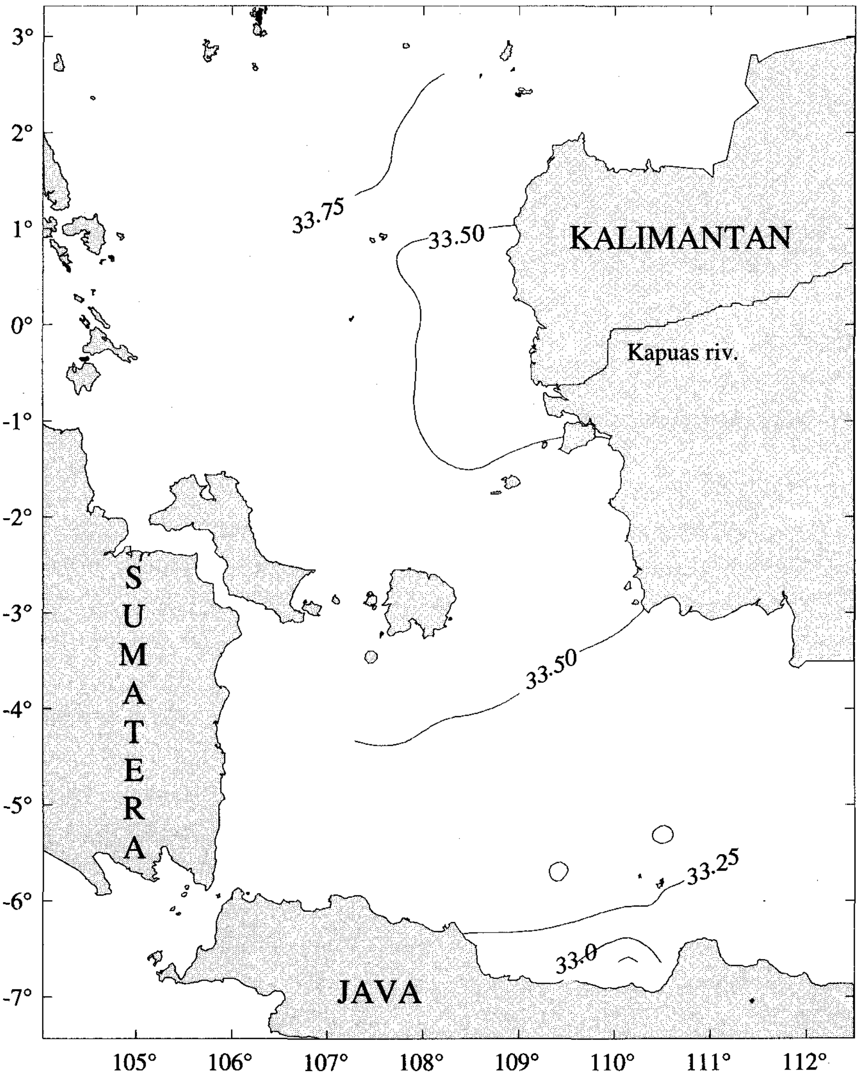

Figure 2 April 1993. Mean salinities for the whole survey.
Gambar 2 April 1993. Rata-rata salinitas di seluruh perairan yang disurvey.

The vertical profiles (Fig. 3) show relatively strong vertical gradients (more than 2.5°/₀₀) on the Javanese coast and a good stratification of waters. Inversely, the waters of the Karimata Strait tend to be homogeneous when the bottom goes up. In the farthest North, a weak vertical gradient reappears thanks to the presence of waters at 34°/₀₀ in depth.

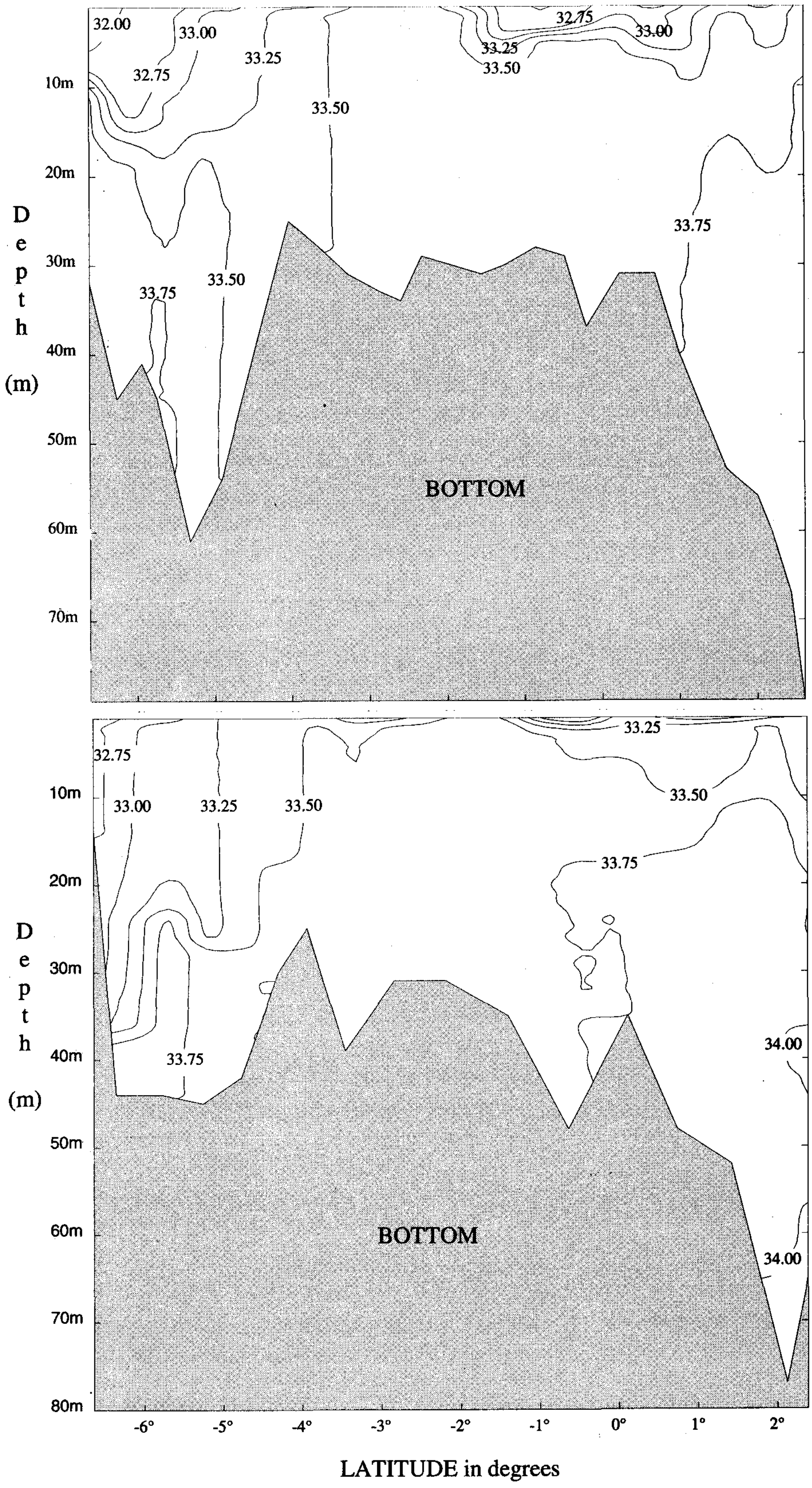

Figure 3 **April 1993. Go (up) and back (down) profiles of salinity.**

Gambar3 **April 1993. Penampang tegak salinitas pada saat pergi (atas) dan pulang (bawah).**

The to and from trips show that the desalinization and its movement concern particularly the East side of the strait. On the Javanese coast during a period of ten days, the desalinization has been clearly progressing, thanks to the vertical mixing (homogenization).

Taking into consideration the superficial measures set up in the strait, Wyrtki (1961) described an invasion of the Javanese basin by neighbouring waters at 32.8‰ coming from the North. Although the observations of April 1993 concern the end of the wet season, the vertical profiles seem well to indicate that the desalinization is only superficial and that an important proportion of waters, pouring into the Java Sea, keeps a high salinity.

The abundance of fish

In the going trip as well in the return, the values of average density are low, if compared to those found in the same period along the Javanese coast (Petit *et al.*, 1997) or in the two great surveys of October 1993 and February 1994 (Petit *et al.*, 1995). In the going trip, the average values decrease as soon as the Java Sea is left and increase just when arriving at the fishing zone (Tab. 1). In the return trip, the same phenomenon is noted, taking into consideration that the average on 24 hours, which is high, before the last day, find its value strongly increased by the meeting of a very important aggregation in the South of Belitung Island.

A detailed analyze of average schedules (Fig. 4) shows that except the strong densities found at the proximity of the fishing zone, the maxima are found in the vicinity of Karimunjawa islands, Karimata and the South of Belitung Island. There could be an island effect of about 40 miles range, but according to the established prospecting, this effect is not distinct from a nocturnal effect on the populations which exists more or less generally. The difference of behaviour between night and day, following the observed zones, is relatively clear. The night/day density ratio decreases when leaving the Java Sea (Tab. 1) and only becomes strong in the fishing zone (Lat. 2°30N).

Spatial structure of populations

The results of the spatio-temporal distribution of the densities analysis are not illustrated. The variograms on the going trip show the existence of a structure of approximately 9 miles of distance (dimension sensibly the same as the one in the Java Sea). At a greater scale, should exist another structure of 75 miles of range, which corresponds to the distance covered day and night and which only reflects the variations of nycthemeral abundance. On return trip, there could also exist another intermediary structure of about 40 miles. But more data are necessary to study it. The fishing zone presents a structure of small dimension (4 to 8 miles). The analysis of that structure is made moreover (Potier *et al.*, 1997) in relation with the distribution of the aggregations and the seiners.

Vertical distributions

Their nycthemeral variations have been represented as percentage per layer of integration of 10 m in 4 hours of interval.

The existence of a migratory behaviour is known from vertical moving of maximum of abundance. This simple model assumes that the analyzed population is homogeneous. In a milieu where coexist the pelagic and semipelagic fauna, that is apparently the case in every region, the different behaviours between the two faunas can lead to a change of distribution hardly interpretable. Taking into consideration the nycthemeral relations of density, in this case, can help to understand the observed phenomena.

The migrating movements between night and day have been noted in the same season in the Javanese basin (Petit *et al.*, 1997). Along the survey, they appear through the variations of average density as well as in nycthemeral density ratio. To illustrate these movements, vertical distribution profiles are represented in the 3 sectors which, regarding the environmental conditions and level of abundance, appear as characteristics.

In the fishing zone by Lat. 2°30 N, the depth exceeds 50 meters. The nycthemeral ratio indicates the presence of a great proportion of semipelagic fauna (the abundance is more than twice between night and day, Tab. 1); the variation of vertical distribution in 24 hours shows a clear migrating phenomenon for more than three quarter of the present biomass. The behaviour is complex : a first upward movement takes place at nightfall, but a second one seems also to occur in the hour which precedes the dawn, while, apparently, no parameter of environment has been changed. Such fraction of semipelagic population disposes seemingly of an internal clock, which allows it to adjust its migration while nothing, however, indicates the proximity of the dawn. As the phenomenon has been pointed out in several places in the Java Sea, it could be characteristic of the *Decapterus russelli* population.

In the Karimata Strait, the depth is lesser, generally less than thirty meters; the vertical distribution between the day and night is more stable; a slight nocturnal migration remains and the nycthemeral ratio is close to 1; we can draw the conclusion that the proportion of semipelagic fauna is here very low.

In the Java Sea, the depth exceeds 35 meters in general , at least in the explored zone. The nycthemeral ratio is higher than 1. The vertical movements can be variable in intensity although they always exist. These fluctuations are perhaps due to the variable importance of the proportion of semipelagic fauna. The sub-superficial levels, by day, weaken more or less. By reference to the time variations of density, although become weak, the nocturnal double movement described in the South of the China Sea (trip Semarang - Karimunjawa Islands) is observed again.

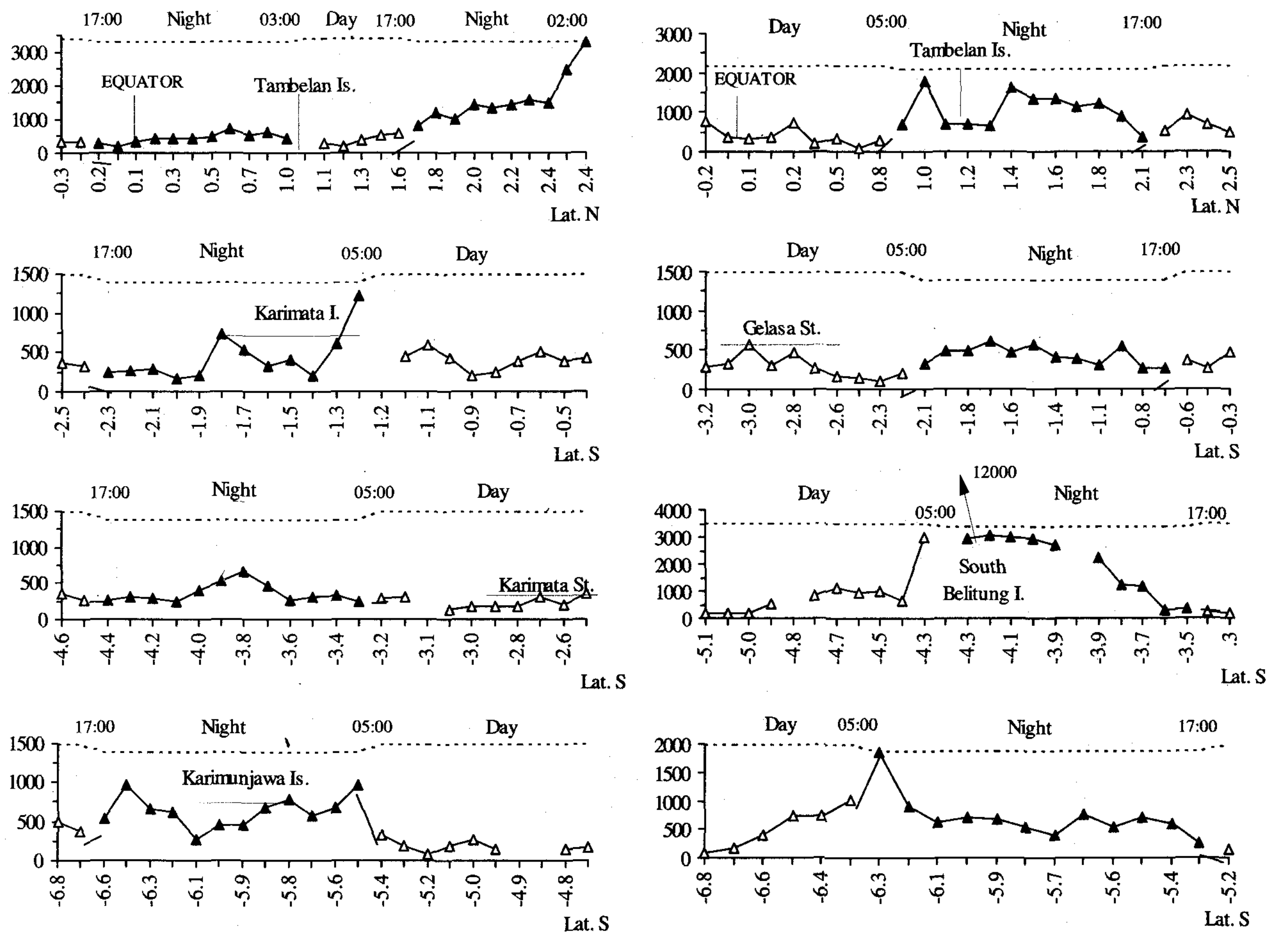

Figure 4 **From the bottom up, towards the North, the hourly mean density per mile (relative unit) ; go (left) and back (right).**

Gambar 4 **Rata-rata kepadatan per mil pelayaran (unit relatif) menurut perubahan waktu pada saat berangkat (kiri) dan kembali (kanan).**

Table 1 **Relative daily densities by mile during the survey 31 (April 1993). D = day transect; N = night transect; the locations are the mean positions of the consecutive day and night transects.**

Tabel 1 **Kepadatan harian (relatif) per mil selama survey 31 (April 1993). D = transek siang; N = transek malam; lokasi merupakan rata-rata posisi transek secara berturutan siang dan malam.**

APRIL 1993	(Survey 31)	D1	D2	D3	D4	Fish zone Day
ONE WAY	Mean	248.1	251.9	392.4	323.4	541.2
	Number	64	68	76	30	72
	Variance	31925.2	21589.6	26645.8	22488.8	87412.3
		N1	N2	N3	N4	Night
	Mean	638.4	357.6	391.1	432.6	1293.1
	Number	80	78	76	71	65
	Variance	69540	24464.4	63349.3	53781	181530
	(N/D)Ratio	2.6	1.4	1	1.3	2.4
	Mean Density by 24h	443.3	304.8	391.8	378	917.2
	and Location	110°18E 5°45S	109°46E 3°05S	108°28E 1°25S	107°40E 0°53N	107°34E 2°35N
RETURN		D4	D3	D2	D1	
	Mean	405.8	410.7	323.8	459.7	
	Number	61	67	85	84	
	Variance	113522	1336317	54913.2	157.386	
		N4	N3	N2	N1	
	Mean	733.6	1948.4	428.5	1033.9	
	Number	83	56	82	84	
	Variance	216447	2248372	18603.3	205434	
	(N/D)Ratio)	1.8	4.7	1.3	2.2	
	Mean Density by 24h	569.7	1179.6	376.2	746.8	
	and Location	109°33E 5°53S	108°01E 4°04S	107°17E 1°41S	107°23E 1°22N	

The aggregations

The dense concentrations of detection found in the area appear to be more aggregations than schools with a well-delimited form. These latter, of lower reverberation, are found particularly in the shallow zones (border of the coasts).

The localization and abundance of these shoals are presented in Figure 5 and Table 2. On go and return trips, they are detected near the bottom and go away only during the night. That original distribution, noted yet along the Javanese coasts (Petit *et al.*, 1997) seems to be a seasonal behaviour and can be related to the optical characteristics of the waters. The richest zone is the one in the Java Sea where they are preferentially situated, in the northern and southern slopes of the basin. The return trip not illustrated here, furnishes the same type of distribution.

In the Karimata Strait, the aggregations tend to be more numerous at night and the proportion of benthic aggregates is clearly higher. It seems that, here, the aggregations concern much more the benthic fauna than the pelagic one.

Coming near the fishing zone, the density of shoals increases. Their abundance at night and in open sea could result from a change of local behaviour induced by the light attraction of seiners. Whatever it may be, from South to North, we can guess also here the existence of three zones : the Java Sea, with its shoals on the slopes, leaving the bottom at night, the area of the strait with shoals apparently benthic and the fishing zone of the South of China Sea with aggregations which have a behaviour linked to the alternation of day and night, such as in the Java Sea.

Table 2 April 1993. Number, mean relative reverberation and number by mile of shoals along the go and back routes. (% in water : percentage of shoals out of the 5 meters close to the bottom).

Tabel 2 April 1993. Jumlah, rata-rata pantulan relatif dan jumlah kelompok ikan per mil sepanjang jalur berangkat dan kembali (keberadaan kelompok ikan lima meter diatas dasar).

		OUTWARD ROUTE			RETURN ROUTE		
		DAY	NIGHT	TOTAL	DAY	NIGHT	TOTAL
Semarang to Lat.3°S	Number	23	13	36	21	4	25
	Reverberation	154	171	160	126	76	118
	% in water	39	46	42	38	100	48
	Number/mile			0.17			0.15
Lat.3°S to Lat.1°N	Number	3	17	20	11	8	19
	Reverberation	269	116	139	118	67	97
	% in water		29	25	9	75	37
	Number/mile			0.07			0.08
Lat.1°N to Fishing zone	Number	2	9	11	8	8	16
	Reverberation	114	152	145	131	109	120
	% in water		56	45	88	25	56
	Number/mile			0.12			0.16
Fishing zone	Number	10	11	21			
	Reverberation	173	208	191			
	% in water	10	64	38			
	Number/mile			0.15			

All that precedes concerns aggregations of small dimension, of the order of dozen meters or more. In return trip, leaving the Gelasa Strait (or Gaspar Strait), there is a shallow zone (23 meters) slightly sloping towards the center of the Javanese basin. On the depth of 25 meters, one of the highest aggregations among those detected during all the surveys has been found. The increase of density has begun towards midnight and continued till the dawn; At three o'clock in the morning, the values have culminated to 16,000 (relative unit per nautical mile), so a density 20 times higher than those measured at the same latitude in the going trip. A perpendicular trip at the followed route, during three miles did not allow to reach the borders. The aggregation is still in contact with the bottom, but 50% of the biomass are between 10 and 20 meters. A sampling (pelagic trawl) has only caught some adult fishes (*Selar crumenophthalmus*) and the quasi totality of the catch was composed of juveniles and larvae. At dawn, the densities have considerably fallen to at least 1,000. This confirms that the shallow zones of Java Sea shelter nurseries of pelagics. Another strong aggregation, but of less importance, will be found near the cape of Mandalika, near Semarang, in February 1995, on analogous depth.

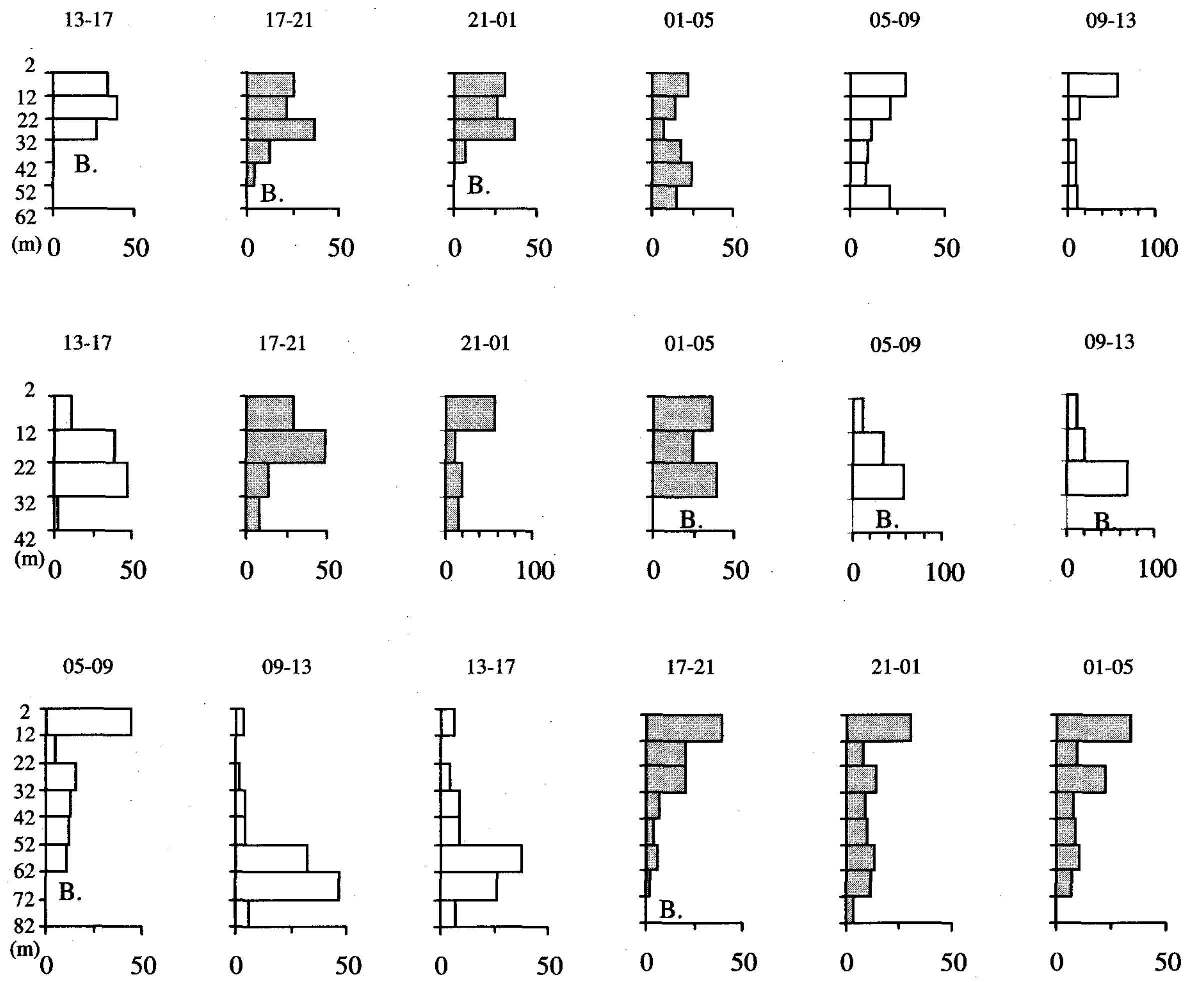

Figure 5 **Three aspects of the vertical distribution of the density (in percentage) during the day-night cycle. Up to down : in the Java Sea (from Lat. 6°50 S to 4°28 S), in the Karimata Strait (from Lat. 2°41 S to 0°13 S) and in the fishing zone (Long. 107°38 E, Lat. 2°31 N).**

Gambar 5 **Tiga aspek distribusi tegak kepadatan (dalam persen) pada siklus siang dan malam. Dari atas kebawah : di Laut Jawa (dari 6°50 hingga 4°28 LS), Selat Karimata (dari 2°41 hingga 0°13 LS) dan di daerah penangkapan (107°38 BT, 2°31 LU).**

CONCLUSION

The realization of that survey, linking the Javanese waters to those of the South of China Sea at that time, presents a particular interest, due to the fact that a great part of the fleet of seiners operates in the North. The collected environmental observations confirm its validity because the trips have allowed to analyze the distribution of densities in a time where the haline gradients are practically the strongest (with those found in the East of the Java Sea, in February). The haline descriptions show clearly the existence of 3 zones, the more salted being found as the richest in fishes, where the seiners operate (more than 3 times richer than the Java Sea at the same time).

But the study of the abundance and distribution of the fauna shows also that the haline zonation should correspond to a zonation of fish populations, at least in that season. They are :

- the rich zone, in the North, with a semipelagic dominance, presenting a very remarkable nycthemeral migrating behaviour,
- the poor zone of the Karimata Strait, where proportionally the pelagic and benthic faunas are dominant (the migrating behaviour is not clear),
- the Java Sea, where there is a much richer and semipelagic fauna of which the behaviour is found to be the intermediary between the ones in the previous zones.

The haline zonation is thus found associated to a fauna zonation, but abundance and salinity are not as much as correlated. The Java Sea appears in that time to be richer than the strait while the latter is more salted. The fishing realized in a considerable aggregation in the North-West of the Java Sea confirms its original character in the functioning of regional ecosystem. It is interesting to underline that after the encountered haline situation, such nursery is found in the basin where the conditions of desalinization persist in a prolonged way. A part of the detected biomass in the Java Sea corresponds to larvae and juveniles. The samplings with appropriate equipment, which was not available during the Project, could allow to better estimate, with acoustics prospecting at various thresholds, that part of the seasonal biomass.

The haline situation, as seen, is not the only important factor which determines the distribution of the abundance. In these three regions, it is clear that the increase of densities is due to the presence of semipelagic fauna; the appearance of this latter is related to the increase of the depth : the richest sector is the fishing zone, and it is the deepest zone. The poorest sector is found to be the shallowest, which is the Karimata Strait. Based on that notion, it could be supposed that in that season, the deepest zone of the Java Sea should be the richest. It is not the case. The maximum of abundance seems to be located in a bathymetric stripe between 25 and 40 meters, at the border of the strongest desalinization, but not in the deep zone, that could guarantee a better environment if those populations were sensitive to the low seasonal salinities. Due to the absence of other information for the moment, it seems that the majority of the fauna of the Java Sea occupies a preferential bathymetric stratum, in relation with its vital needs, which could be of tropic order and under the constraint of competitiveness with the presence of other species. Among the most caught species in the Java Sea, *D. russelli* is the species of which the capture remains ahead almost along the year (Potier and Sadhotomo, 1995). The preferential zonation, pointed out, seems to represent its habitat, at least for the remaining bulk in wet season. It is likely that a part of the stock of dry season, at the arrival of the rains, has to seek for shelter in the same bathymetric levels of neighbouring islands.

Let us confront these observations with the theory of Hardenberg about the migration of *layang* (*Decapterus spp.*) (Hardenberg, 1937). The different acoustic surveys realized during the Project have brought sufficient information in that domain, all the more interesting since it completes the information furnished by commercial captures. Until now, these surveys are lacking of precision as well as knowledge of capture places. In his theory, Hardenberg suggested the existence of different populations of *layang* in the Java Sea; one of them should come from the South of China Sea and should derive (eggs and larvae) and/or migrate (immature) to the Javanese basin during the west monsoon. Hardenberg did not differenciate between *D. macrosoma*, oceanic, and *D. russelli*, more neritic. Did he only wish to talk about the latter ? (the other species being absent in the Java Sea in wet season). He considered that the species seeks for clear waters higher than 32‰; but in wet season, although the whole strait is not entirely invaded by desalinized waters, the risk of desalinization is obvious and the waters, in consequence, are turbid. The drift, or the migration, of that species along almost 500 km through waters not favourable is not impossible but unlikely in full desalinization. Could the movement take place in the inter-season ? The currents are less favourable. The interseason is approximately the period where this survey has been done. The haline conditions are favourable (waters at 33.5‰), but the likely obstacle is not found there. The last observations in the Java Sea, as in the South of the China Sea, seem to indicate that the species is semipelagic and that it has a liking for a bathymetry more important than in the strait. The shallowness of this latter seems to be an hindrance. As noticed, it does not seem that, there, exists a perfect continuity of populations between the Javanese basin and the South of China Sea. The fauna of the strait is thus of pelagic and benthic dominance, the semipelagic fauna, even if existing there, is of less importance than in the North and the South. To recall a drift from the North for explanation of appearance of eggs and larvae in the northern edge of Java Sea in wet season does not seem necessary regarding the huge aggregation of larvae and juveniles found in the South of Belitung Island. It was very near the "triangle of desalinized waters" pronounced on Sumatra which, according to Hardenberg, cannot contain the species, but perhaps its larvae. Works oriented precisely on the recognition of nursery in the Java Sea could clear up the interrogations on the migrating movements of the species, necessarily related to its reproduction.

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DISCUSSION

(Chairman Dr. WIDODO)

Dr. NURZALI

Q : - Yesterday, you told us that you focused your surveys on the eastern part of Java, because there were no fish in the western part confirmed by the absence of fishermen. Now, you show us fish aggregations here (West part) and big schools there... Can you explain this contradiction ?

A : - These aggregations have been sampled; they were composed of juveniles and larvae. That could explain why fishermen were not on these concentrations. Some time ago, Hardenberg said there were migrations between the Java Sea and the South China Sea. We performed this survey in the South China Sea in order to make our own opinion on this hypothesis and to estimate if it is right or not.

Dr. ILAHUDE

Q : - Is it possible that species from the Flores Sea, living in high salinity and entering the Java Sea, can penetrate the Karimata Strait and its low salinity ? Can they mix together with high salinity populations of the South China Sea ?

A : - Our results are based from a single survey; thus, we are not able and allowed either to solve the enigma. We have seen, here, that the salinity was different between the Java Sea and the Karimata Strait. We might think that the values of salinity met in the Karimata Strait were better and more favourable for fish that than those in the Java Sea. It might be then possible that fish from the South China Sea to enter the Java Sea. Meanwhile, depth remains an obstacle for the semi-pelagic populations whose habitat is referred to. We may guess that the adults cannot break through the shallow Karimata Strait; only the juveniles and the larvae could drift in the currents.

Q : - Are there any other factors which influence the pelagic and semi-pelagic fish density and their behaviour besides the salinity, such as the temperature for instance ?

A : - We may think that the temperature does not influence. Dr. Ilahude has put forward the same opinion. The variations of temperature are very low in these areas, about 1° or 2° C per year. The Karimata Strait is not similar to the Makassar Strait or else where upwelling can be found. In this region, we have the same temperature all along the year and thus, this factor does not play on the distribution and the movement of the fish. We focused this discussion on salinity because it is one of the few factors we studied in deep. We could discuss on turbidity, transparency and light penetration as well because it is obvious that this latter is an important factor for the reproduction in the Java Sea. But, the underwater transmission of light remains difficult to study.

THE USE OF ACOUSTIC METHOD FOR OBSERVING THE PLANKTON DISTRIBUTION IN THE SOUTHERN PART OF SOUTH CHINA SEA

E. MULYADI, S. SALIM

ABSTRACT

Some acoustic surveys have been conducted in the southern part of South China Sea, with an EKS 120 sounder equipped with a QM MK II integrator, and with an EK400 (120, 38 kHz) sounder connected to a QD digital integrator.

During the period June 1981 - December 1983, the average millimetre deflection ($\bar{M}$) was measured through evaluation to determine biomass differences between the night and the day time. The vertical migration of the scattering layer of plankton is a dominant factor of the biomass abundance. The movement pattern of plankton during the day time tends to concentrate it in the deeper waters, while during the night it tends toward the surface layers. The small pelagic fishes tend to move vertically, following the movement of plankton. The knowledge of plankton distribution pattern could be considered as one of the factors which may be used to determine suitable fishing method and gears.
KEYWORDS : acoustics, echo-integration, pelagic fish, plankton, South China Sea.

ABSTRAK

Beberapa survey akustik telah dilaksanakan di perairan sebelah Selatan Laut Cina Selatan pada periode Juni 1981 hingga Desember 1983. Rata-rata defleksi nilai echo-integrasi (mm) diamati untuk menentukan perbedaan besarnya kelimpahan biomassa pada periode siang dan malam. Ruaya tegak lapisan terhambur yang disebabkan keberadaan plankton merupakan faktor yang mendominasi besarnya biomassa. Pola pergerakan plankton pada siang hari cenderung berkonsentrasi di perairan yang lebih dalam kemudian bergerak ke lapisan permukaan pada malam. Ikan pelagis kecil cenderung bergerak mengikuti pergerakan plankton. Pengetahuan pola sebaran plankton dapat dipertimbangkan sebagai faktor penentu dalam penentuan metode dan alat tangkapnya.
KATA KUNCI : akustik, echo-integrasi, ikan pelagis, plankton, Laut Cina Selatan.

Acoustic method has been used since a long time, in fishing exploitation. In Indonesia, some of fishing industries use the acoustic method either for pelagic or demersal exploitation. In addition, in the eastern part of Indonesia, almost all trawl fishing vessels are equipped with sounders to detect shrimps on the sea bed.

Besides the private companies, the Indonesian Research Institutes also use acoustic method to carry out the resource surveys, especially on small pelagic fisheries.

Since fish, and plankton as well, have a diurnal migration, therefore acoustic method would be useful to predict those resources.

The CIDA/FAO Indonesian Fisheries Development Project (INFIDEP) within its activities has conducted acoustic surveys in the southern part of South China Sea which covered an area of approximately 70,000 nautical mile square, from 0° to 5° North and from 105° to 109° East. Some large islands such as Natuna, Tambelan, Serasan, Siantan, Jemaja and Midai (Fig. 1) were surveyed between 1981-1983; three surveys have been performed (Johannesson, 1984):

No. cruise	Date	Area covered
Cr. 01/8106-07	22/06/1981 - 27/07/1981	Total area
Cr. 03/8211-12	10/11/1982 - 06/12/982	Partly
Cr. 03/8311-12	06/11/1983 - 04/12/1983	Natuna and Anambas

MATERIAL AND METHODS

Material

The R/V Tenggiri was used for conducting the acoustic survey. Fitted out for purse seine and long line, it was also equipped with 2 integrator systems. The first was a SIMRAD QM-MK-II, with a dual-channel analogic integrator, connected to a EK-S 120 (120 kHz) scientific sounder. The second system was a SIMRAD QD multi-channel digital integrator, connected to a EK-400 scientific sounder, with two frequencies (120/38 kHz).

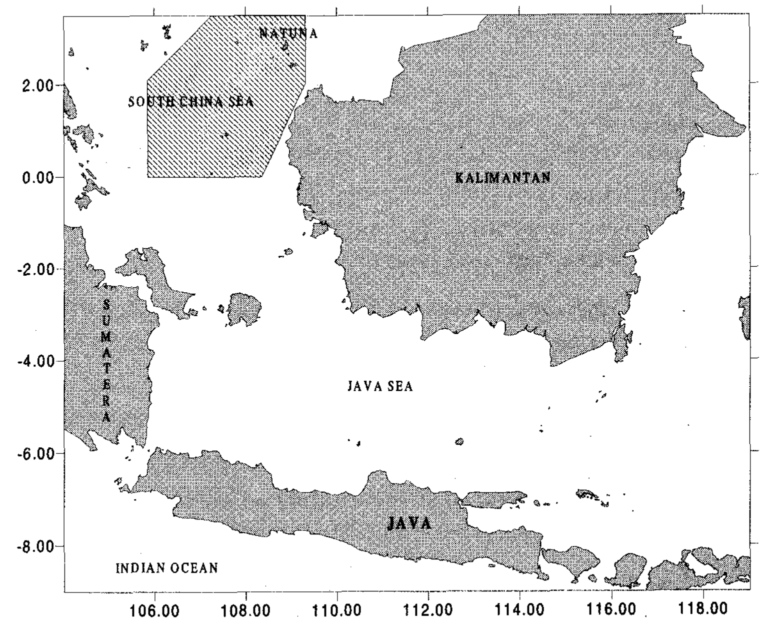

Figure 1 **Survey area.**
Gambar 1 **Daerah survey.**

Methods

The surveys were achieved through parallel grids for the three cruises and also combined with zigzag tracks for the area close to the island. The speed was 10 knots. The acoustic data from analogic integrator, were recorded on log-sheet every 2 nautical mile square along the track, while the data from QD digital integrator system, were recorded automatically on the data terminal.

The data used for observing the distribution on plankton pattern come from analogic integrator with EK-S 120 as the deflection measured in millimetre (M) during the night and the day time. The values of M were corrected in order to avoid the sound disturbance (false echo integration) on a thermal paper. The correction was done through adjustment on the recorded values of M (graphical) related to the traces on the echogram (Johannesson and Mitson, 1983).

The setting controls, for each equipment, can be described as follows :

a. Analogic system

Sounder : SIMRAD EK-S 120 and 120-25-E transducer, with 10° beam angle, and 10cm diameter radiating surface.

Output power	: 1/1 (maximum)	Recorder gain	: 6
Receiver gain	: 0 dB	Mode	: WL (White Line)
TVG Function	: 20 log R/0 dB	Discriminator	: 6 (variable)
Pulse Duration	: 0,3 ms	Range	: 0-100 m
Receiver Bandwidth	: 10 kHz	Sounding Rate	: 125 soundings/min

Echo-integrator : SIMRAD QM-MK-II and Hewlett Packard recorder 7702 B.

Gain	: 20 dB	Bottom Stop	: on (manual reg.)
Scale Expander	: x 10	Integrator Channel	: A 3-50 m; B 50-100 m
Threshold	: 2	Reset	: manual every 2 miles
Speed compensator	: 10 knots (fixed)		

b. Digital system

Sounder : SIMRAD EK 400 interface connected with QD echo-integrator.

Frequency	: 38 kHz	Gain	: 0 dB
Pulse duration	: 0.35 msec	Source level	: 119.4 dB
Recurrence	:125 pulses/min.	Voltage response	: 3.5 dB
TVG	: 64.6 dB	O-Echosounder	: -31.5 dB
Max. Range	: 314 m.	SV Suppress	: -70 dB

Eight layers referenced to the surface, the first from 2 to 10 m depth, the followings 10 m width. Two layers referenced to the bottom, the first from 0.5 to 5.5 m, the second, from 5.5 to 15.5 m.

Threshold : 10 mVpeak.
Scale : 1.00

c. Scanning Sonar

Frequency : 88 kHz
Sector : -90° to +90°
Tilt angle : -3°
Display : PPI/CRT plus recorder
Range : 0-800 m

Besides the corrections on M value, it was also done a partition of M, between fish and plankton values.

Distribution of the plankton during the day and the night time

An observation on the cruise data was done to determine any possibilities on the biomass abundance differences between the night and the day time. This abundance consists of nekton and plankton. Both nekton and plankton were always integrated, due to their predator-prey relationship.

An average value of millimetre deflection was calculated separately for the day (Md)and night (Mn). The results show that, for the survey 8106-07 part I, the values were: Md = 19.9 and Mn = 33.0; that is to say, the ratio Md / Mn was: 0.60. For the part II, the values were: Md = 18.7 and Mn = 32.7; thus, the ratio obtained was 0.57. If part I and part II are mixed, we obtain the value of Md = 19.3 and Mn = 32.4. Furthermore, the ratio was 0.60 (Fig. 2).

The survey 82/11-12 was divided into two parts : the first, Natuna and its adjacent islands, the second, Anambas. The ratio in Natuna island was : 0.42, while in Anambas island it was 0.65 (Fig. 3).

There is an exception, in the first part, where the value of ratio was : 1.04 ($\overline{Md} > \overline{Mn}$) (Fig. 4). In general (6 from 7 observations), the mean deflection by day is lower than by night.

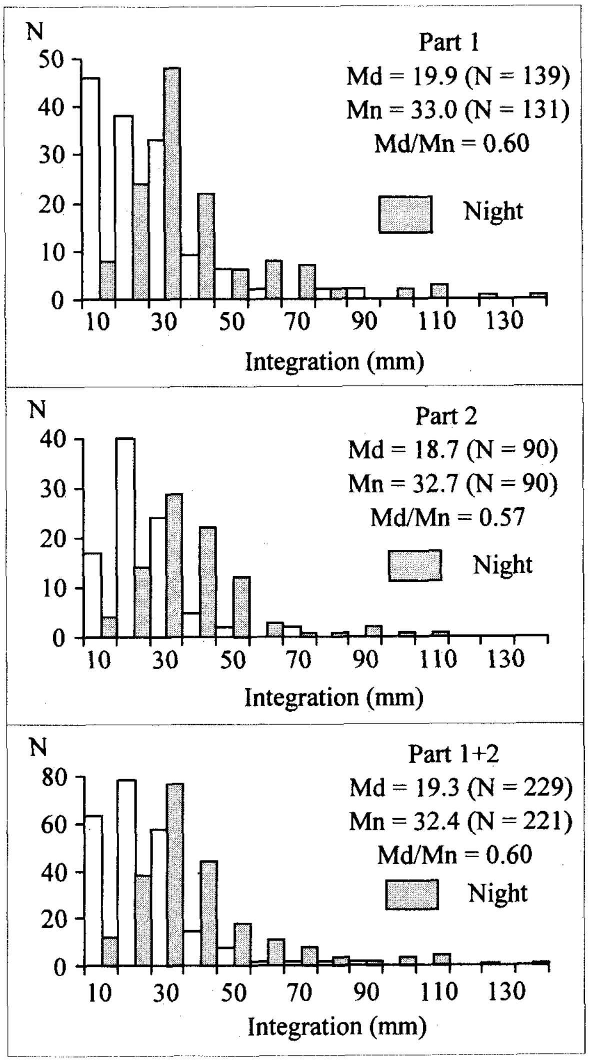

Figure 2 **Survey 01/81 06-07. Frequency distribution of day and night- integration values. Md, Mn = Means of the day or night values.**

Gambar 2 **Sebaran frekuensi nilai integrator siang dan malam. Md, Mn = Rata-rata nilai siang dan malam.**

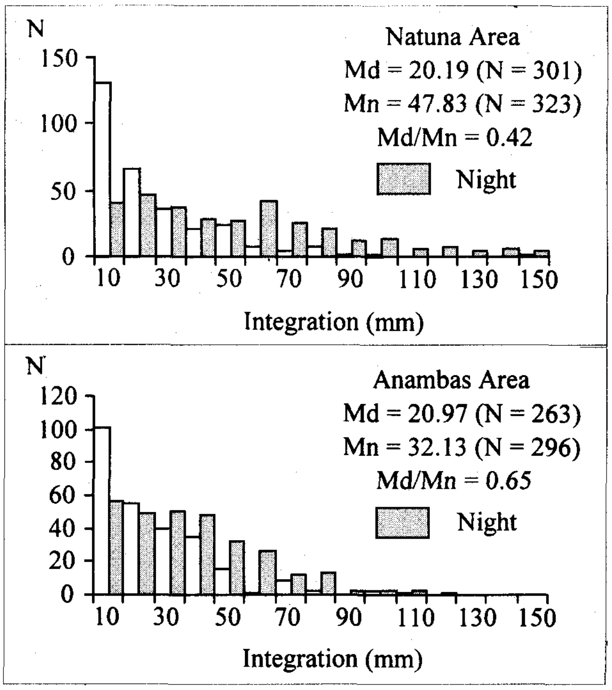

Figure 3 **Survey 03/82 11-12. Frequency distribution of day and night integration values. Md, Mn = Means of the day or night values.**

Gambar 3 **Sebaran frekuensi nilai integrator siang dan malam. Md, Mn = Rata-rata nilai siang dan malam.**

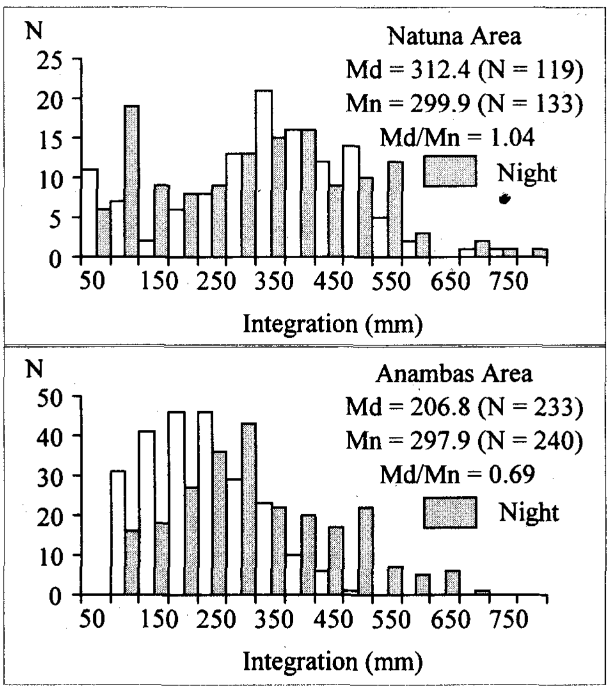

Figure 4 **Survey 03/83 11-12. Frequency distribution of day and night integration values. Md, Mn = Means of the day or night values.**

Gambar 4 **Sebaran frekuensi nilai integrator siang dan malam. Md, Mn = Rata-rata nilai siang dan malam.**

Table 1 . Estimated abundance of small pelagic species based on analogic integrator, data collected during cruise 03/8211-12.

Tabel 1 Perkiraan kelimpahan ikan pelagis kecil berdasarkan data analogic integrator pada pelayaran 03/8211-12.

Area	Stratum No	Stratum (mm)	M-Value M (mm)	Area A (Nm^2)	Conv. Constant C ($t/Nm^2/mm$)	Mean Density pA (t/Nm^2)	Weight factor FP (ratio)	Obs. No (n)	Estimated Biomass (tonnes) Total	Estimated Biomass (tonnes) Weighted
ANAMBAS	I	1-50	24.4	3,567	0.28	4.44	0.65	465	24,575	15,973
	II	51-100	64.6	481	0.28	11.76	0.65	49	8,700	5,655
	III	>100	103.0	18	0.28	18.72	0.65	2	519	337
		Total:	29.5	4,096	0.28	5.36	0.65	516	33,794	21,965
NATUNA	I	1-50	23.4	4,344	0.28	2.76	0.42	388	28,498	11,969
	II	51-100	66.3	1,506	0.28	7.79	0.42	123	27,945	11,737
	III	>100	125.2	200	0.28	14.72	0.42	26	7,011	2,944
		Total:	37.5	6,050	0.28	4.41	0.42	537	63,454	26,650
SERASAN	I	1-50	11.4	2,702	0.28	1.92	0.60	215	8,625	5,175
	II	51-100	74.5	230	0.28	12.52	0.60	16	4,798	2,879
	III	>100	127.8	126	0.28	21.47	0.60	9	4,508	2,944
		Total:	20.9	3,058	0.28	3.52	0.60	240	17,931	10,777
TAMBELAN	I	1-10	7.8	79	0.28	1.29	0.60	8	171	102
	II	>10	12.0	537	0.28	2.01	0.60	58	1,801	1,081
		Total:	11.4	616	0.28	1.92	0.60	66	1,972	1,183

One of those ratio values has been taken as a multiplying factor for the biomass estimation (Tab. 1). It shows that there are differences in term of total biomass and weighted biomass. From a visual observation of echograms, the differences are due to the plankton. It appears that the plankton has a vertical movement: from the lower layer during the day time, it moves toward the upper layer during the night time (Fig. 5).

The movement might depend on the changes of the light penetration in the water. However, Figure 6 shows that another factor can influence the location on plankton distribution, the sea water temperature, because the plankton distribution layer is more concentrated in the deeper thermocline layer. In this case, the temperature is strongly related to the penetration of sun light intensity.

The prospect

Since the movement of the plankton due to the day time changes, it could be connected with a diurnal movement.

Small pelagic fishes are considered as plankton feeders (Pradhan and Reddy, 1962). Sutomo (1989) stated that the areas containing high zoo plankton, quantities are related with a high average catch per hook (catch rate) of tuna. Tuna fishes are not feeding on the plankton directly, but they feed small fishes which are plankton feeders. According to Subani and Sudrajat (1981), there was a strong relationship between a concentration of lemuru and high abundance of zoo-plankton. Then, the relationship between the plankton and the small pelagic fishes is very strong. Another characteristics appears related to the biomass : it is the movement of the plankton. Some opinions stated that fishes were interested by a positive phototaxis because of the feeding.

The plankton distribution pattern is an aspect of the fish behaviour study. It plays a part in determining the fishing method as well as its gear.

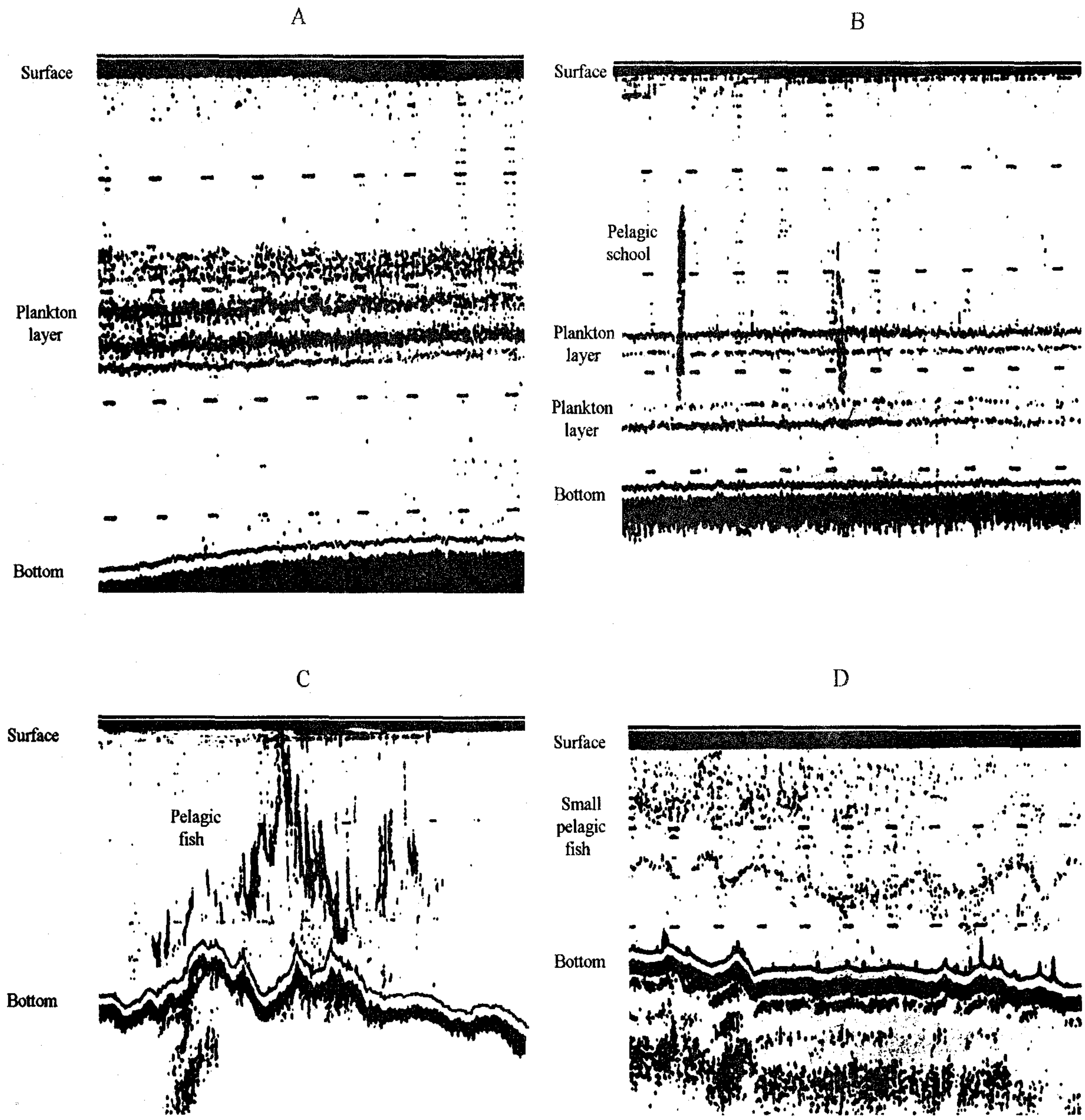

Figure 5 Echo-recording made with EK-S120 (range 0-100 m) during preliminary survey cruise 01/8106-7; (a) typical mid water layer of plancton at night; (b) pelagic school mixed with double layer of plankton; (c) upward movement of pelagic fish at dusk; (d) faint traces of small pelagic fishes without plankton during day time.

Gambar 5 Rekaman gema dengan alat EKS 120 pada kisaran kedalaman 0-100m pada pelayaran awal 01/8106-07; (a) Keberadaan plankton pada malam hari; (b) Keberadaan kelompok ikan pelagis dan lapisan plankton; (c) gerakan kepermukaan ikan pelagis pada petang hari (d) cercah lemah dari ikan pelagis tanpa plankton pada siang hari.

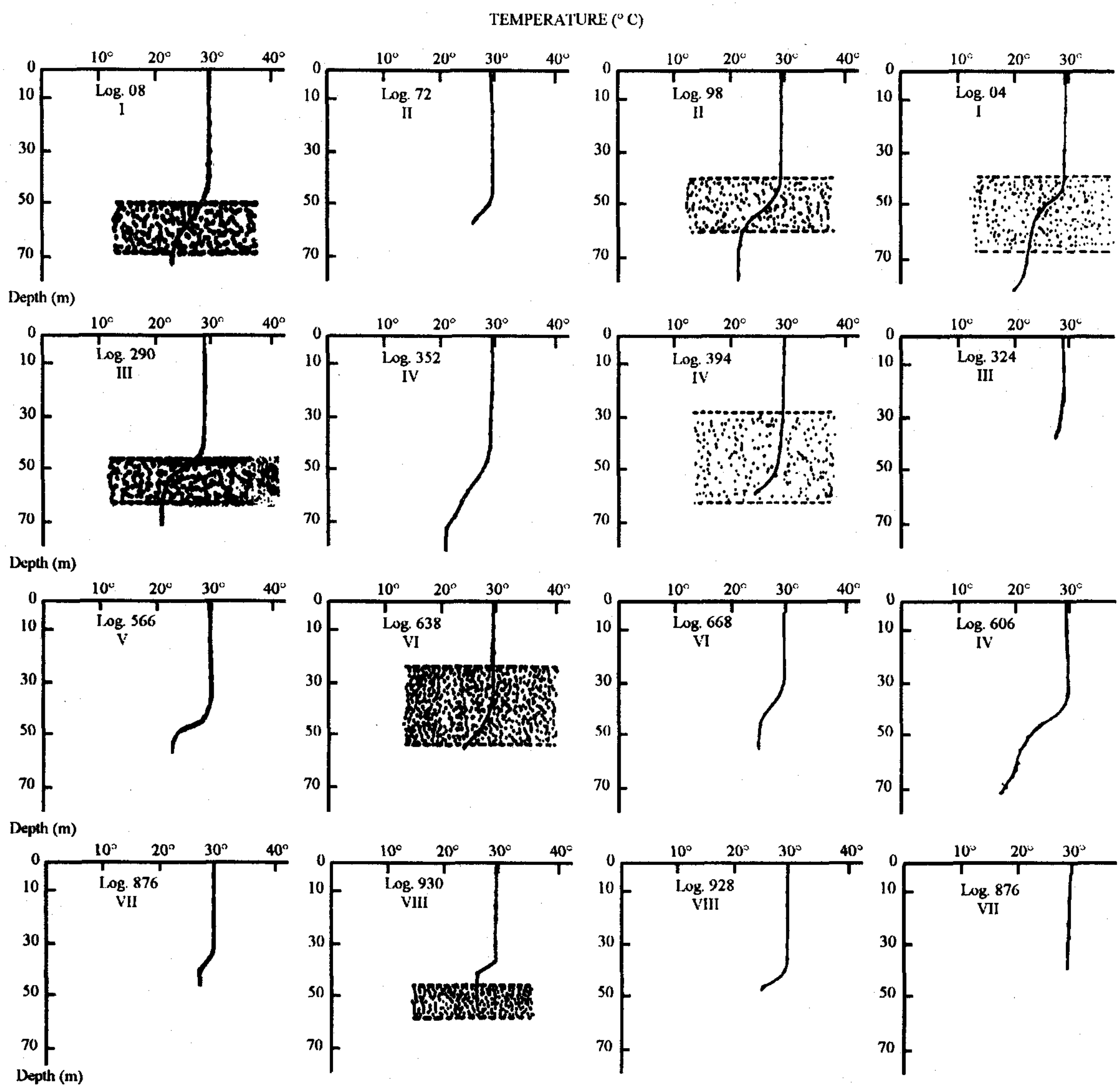

Figure 6 **Measured temperature profiles during CR. 01/8106-07 and corresponding depth locations of observed plankton layers (shaded area).**

Gambar 6 **Penampang tegak suhu serta keberadaan lapisan plankton (*shaded area*) pada pelayaran 01/8106-07.**

Result

Based on the information and discussion, the result can be summarized as follows :

- The movement pattern of plankton during the day time tends to concentrate in deeper waters, while during the night it tends to concentrate to the surface layer (Fig. 5).
- Some small pelagic fishes feed the plankton and the vertical migration of this latter influences the distribution pattern of such fishes.
- The study of the distribution of plankton and small pelagic fish in term of vertical migrating during the day and the night time could be considered as one of selective methods to determine a proper fishing and gear.

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DISCUSSION

(Chairman Dr. WIDODO)

Dr. GERLOTTO

Q : - Have you any information on the proportion in biomass between plankton and fish, because the Pelfish Project did not make any plankton sampling ? It would be valuable to have some.

When you processed these echograms, you had QD values represented by these lines recorded on. Then, you had to decide based on observations, if these deviations were due to fish or plankton or a certain percentage of fish. Can you explain more in details the chosen criteria ?

A : - We used thermal recording paper with size-millimetre height. First, we looked at the recorded line which jumps from the bottom to the upper part of the paper. We deducted this vertical value from the rest. One of those ratio values was taken and used as multiplying factor regarding to the biomass estimation for small pelagic fish based on their respective orders; in this way, is shown the difference between total biomass and weighted biomass. The weighting of the plankton can be then determined. It appeared that plankton was operating vertical movement in such a way that its density was high enough to reach the level of saturation of the measure.

Dr. PETIT

Q : - Did you make plankton sampling during the survey ? Were the catches very different from one sampling to another or steady ? Did you try to relate density of plankton to the echograms ?

A : - According to the paper, it is quite different; in fact, the aim of this paper was to give a description of the relationship between the abundance of plankton and the small pelagic fish.

Dr. SIREGAR

Q : - How did you discriminate the plankton from sediments or suspending particles, because suspending matter is bigger than phytoplankton and therefore the echoes you recorded may come from sediment reflection ? It would be better if you mention also the concentration of micro organisms in order to have more information on fish behaviour.

A : - The authors of this paper made sampling. They separated plankton from the suspending matters. But, in this paper, they did not mention anything about that. The objective was to show the relationship between abundance of plankton and abundance of pelagic fish.

Dr. ILAHUDE

Q : - You made 3 cruises : in July, November and December. Oceanographically speaking, we have a good contrasting seasonal representation. From the figures you have shown, there are almost no differences between these 3 surveys. My first question is : why was there no seasonal differences ? The second one is : in the surroundings of Natuna and Anamba islands, you gave only the ratio values. I personally guess that near the islands, the values should be higher because of the sediments and plankton concentrations; but, again, the ratio remains almost the same. Do you have day and night values ? The night values must be higher.

A : - From the 6 or 7 observations, it has been confirmed that the mean value during the day time was smaller. Nevertheless, there is one exception : around Natuna island, where the value of the ratio was 1.04, which means that the mean in the day time was higher that the mean of the night time.

TENTATIVE RELATION BETWEEN ACOUSTICS AND DYNAMICS. A CASE STUDY : THE PURSE SEINE FISHERY OF THE JAVA SEA[1]

M. POTIER, P. PETITGAS, D. PETIT

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 penggunakan cahaya mereka mengubah penyebaran konsentrasi ikan agar berkelompok disekitar kapal kemudian ditangkap.
KATA KUNCI : operasi penangkapan ikan, akustik, stuktur spasial, ikan pelagis, Laut Jawa.

[1]Reprint from : Interaction between fish and fishing vessel in the javanese purse seine fishery. Aqua. Liv. Resour., 10(3), 1997.

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 ?

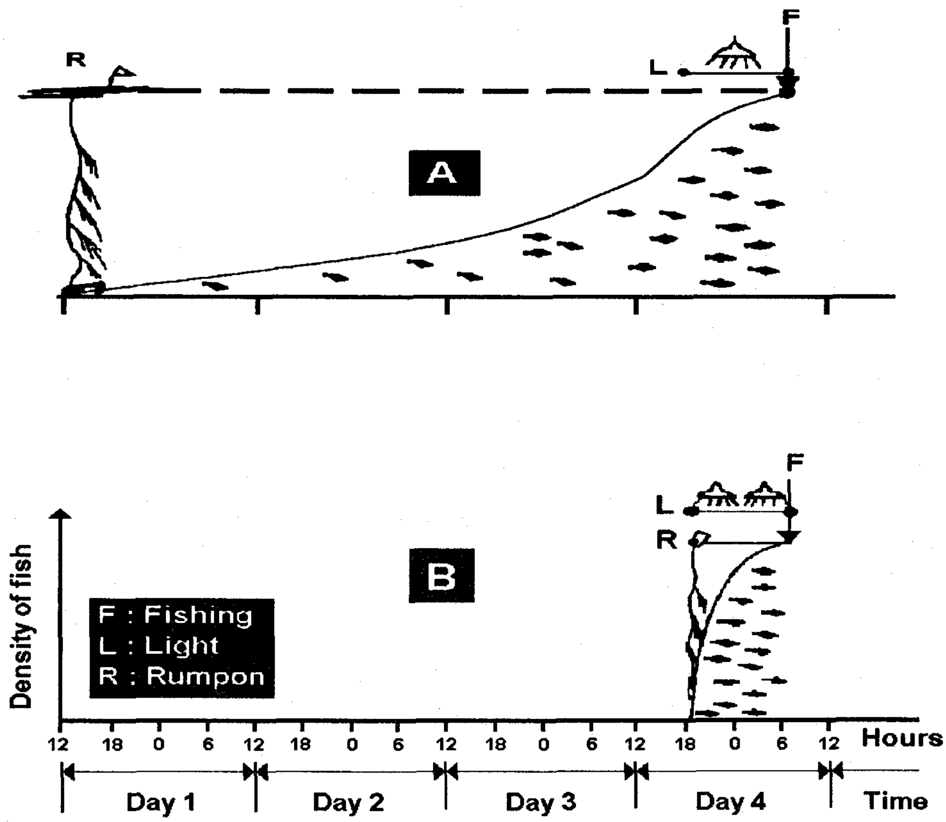

Figure 1 Phases of fish attraction. Old (A) and new (B) fishing tactics.
Gambar 1 Tahapan pengumpulan ikan. Taktik lama (A), baru (B).

[2]Indonesian 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 Project[3], 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.

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[3]Pelfish. 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.

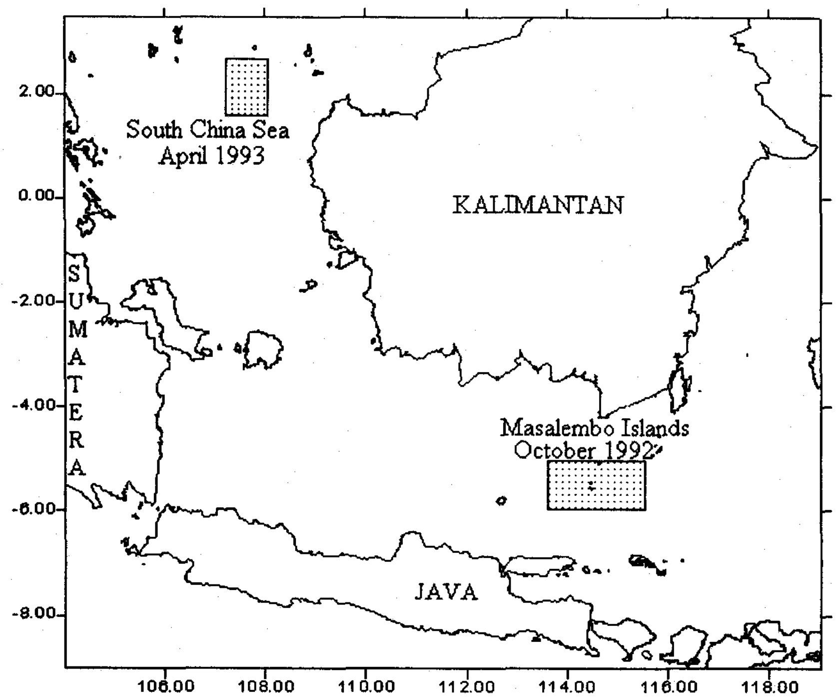


Figure 2 **Location of the 2 acoustic cruises used for the study.**
Gambar 2 **Lokasi 2 pelayaran akustik yang digunakan pada studi.**

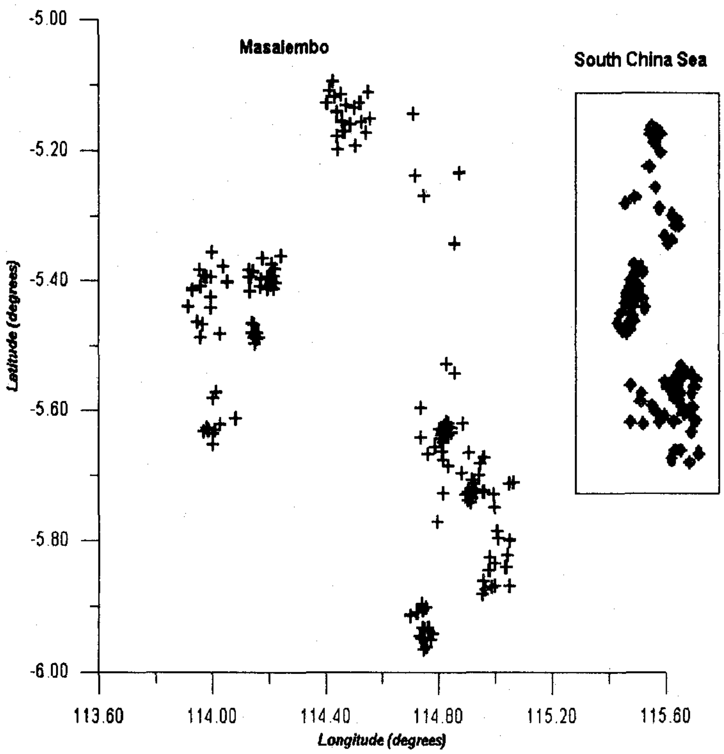


Figure 3 **Locations of the purse seiners on the Masalembo fishing ground in October 1992 and the South China Sea fishing ground (April 1993).**
Gambar 3 **Lokasi kapal-kapal purse seine di daerah penangkapan Masalembo pada Oktober 1992 dan di Laut Cina Selatan (April 1993).**

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

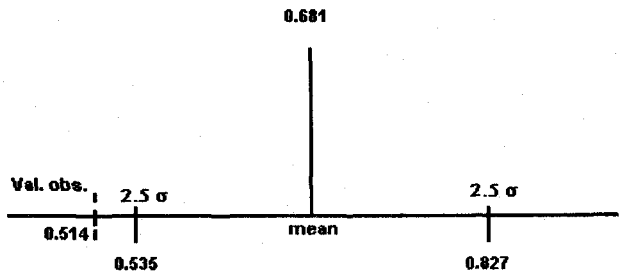
In each cluster, all the distances between boats were computed and the frequency distribution of the distances was estimated.

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.

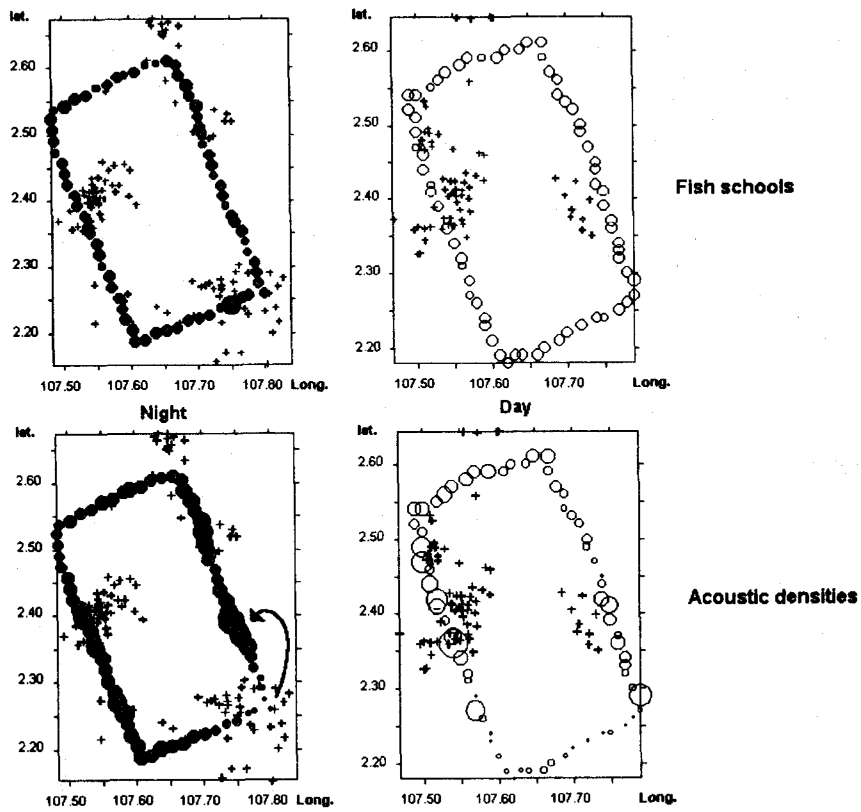


Figure 4 **Acoustic densities and fish schools distribution during the South China Sea cruise in April 1993.**

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

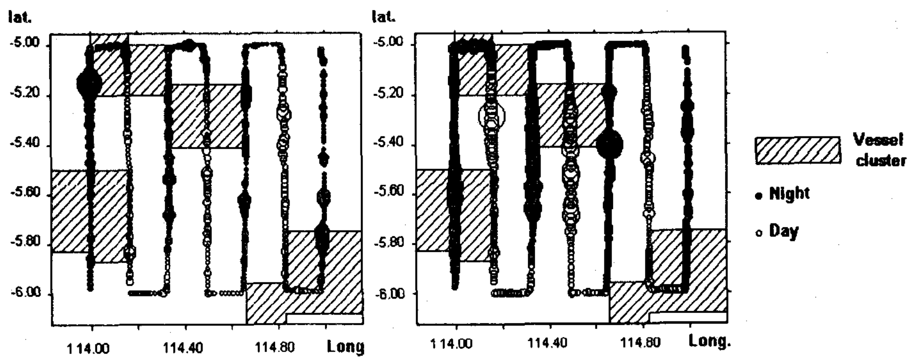


Figure 5 **Acoustic densities and fish schools distribution during the Masalembo cruise in October 1992.**

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

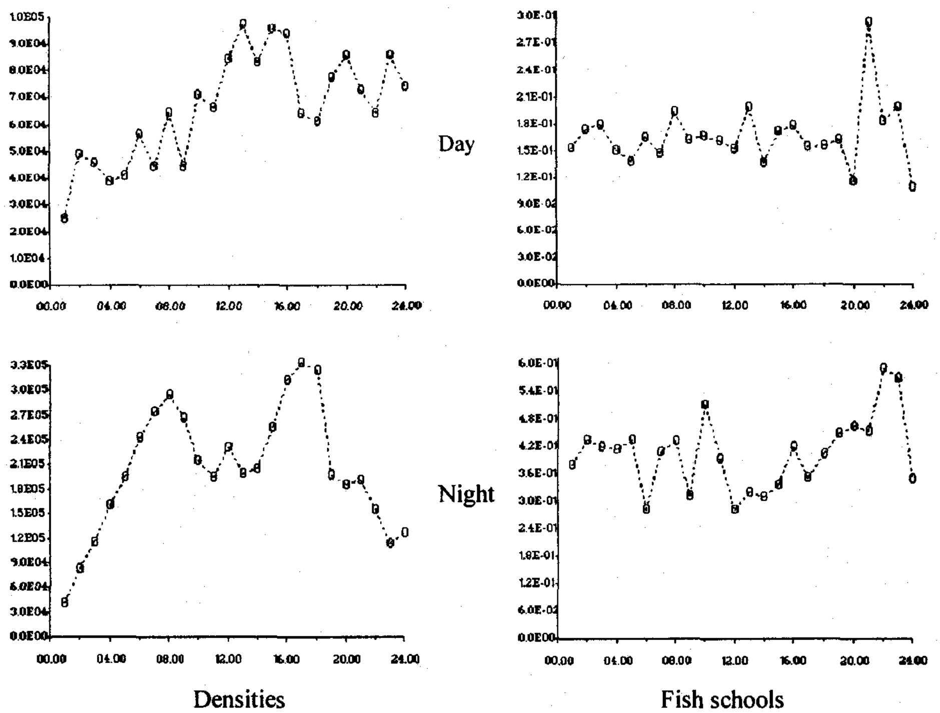


Figure 6 **Variograms on densities and fish schools during the South China Sea cruise (April 1993).**

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

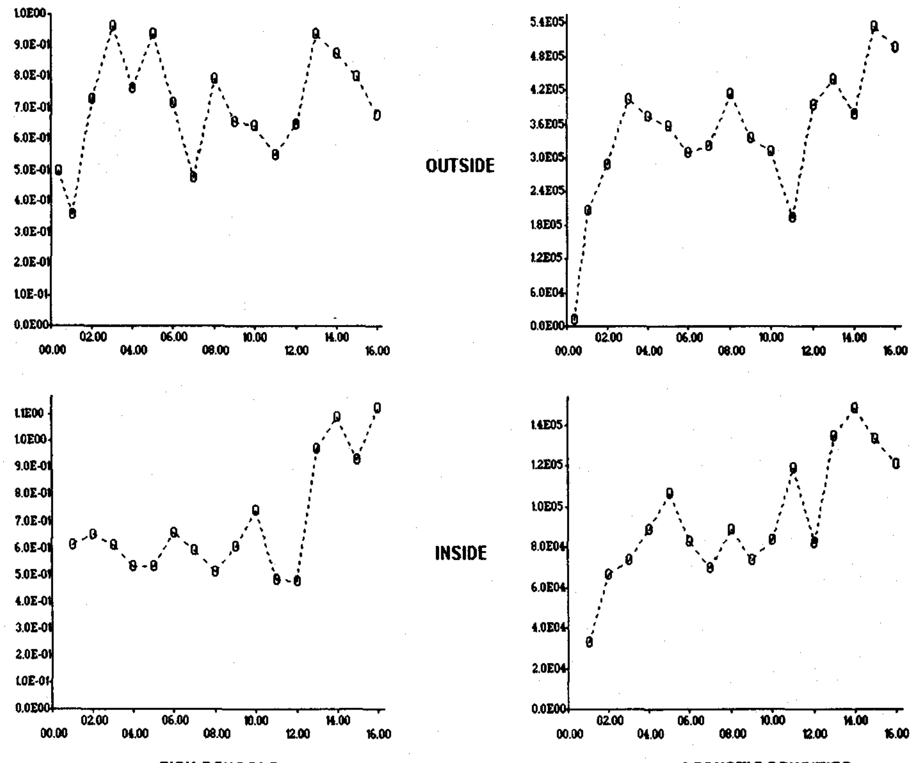


Figure 7 **Acoustic densities and fish schools variograms at daytime during the Masalembo cruise in October 1992.**

Gambar 7 **Variogram kepadatan ikan dan kelompok ikan pada siang hari pada pelayaran di Masalembo 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.

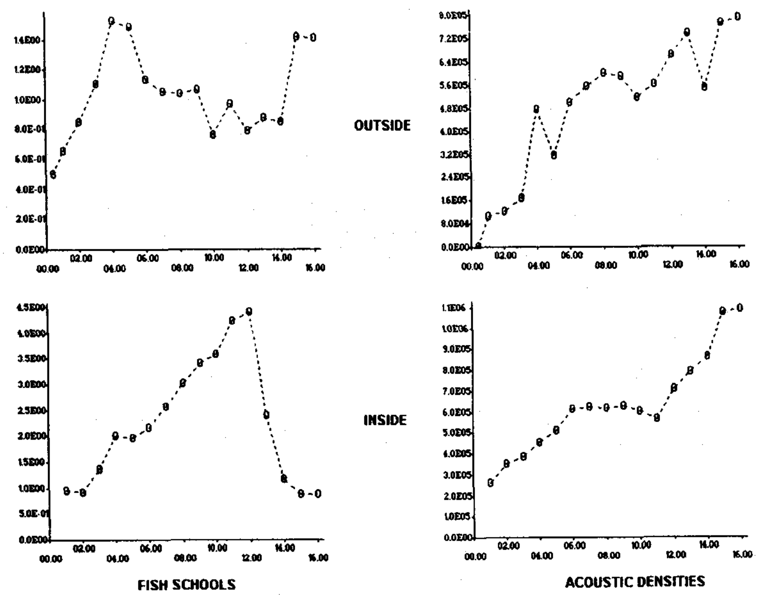


Figure 8 **Acoustic densities and fish schools variograms at night during the Masalembo cruise in October 1992.**

Gambar 8 **Variogram kepadatan ikan dan kelompok ikan pada malam hari pada pelayaran di Masalembo pada bulan Oktober 1992.**

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

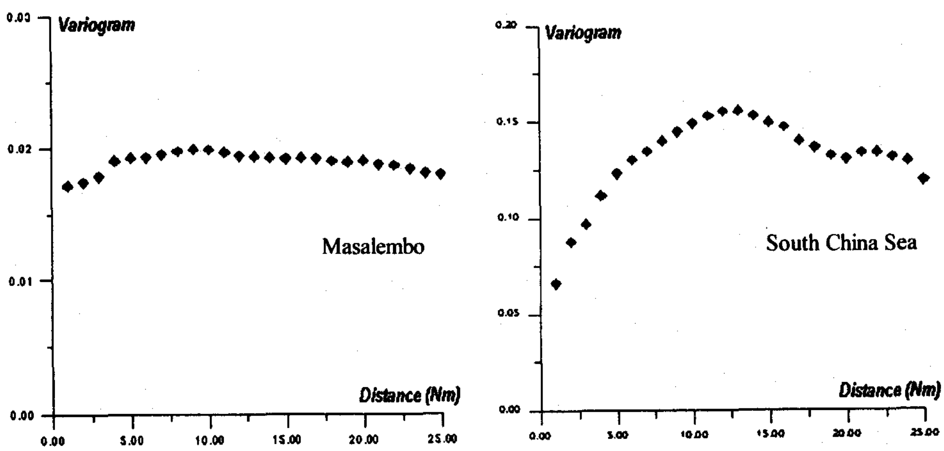


Figure 9 **Variograms of the presence of boats during the Masalembo and South China cruises.**

Gambar 9 **Variogram keberadaan kapal ikan pada pelayaran di Masalembo 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.

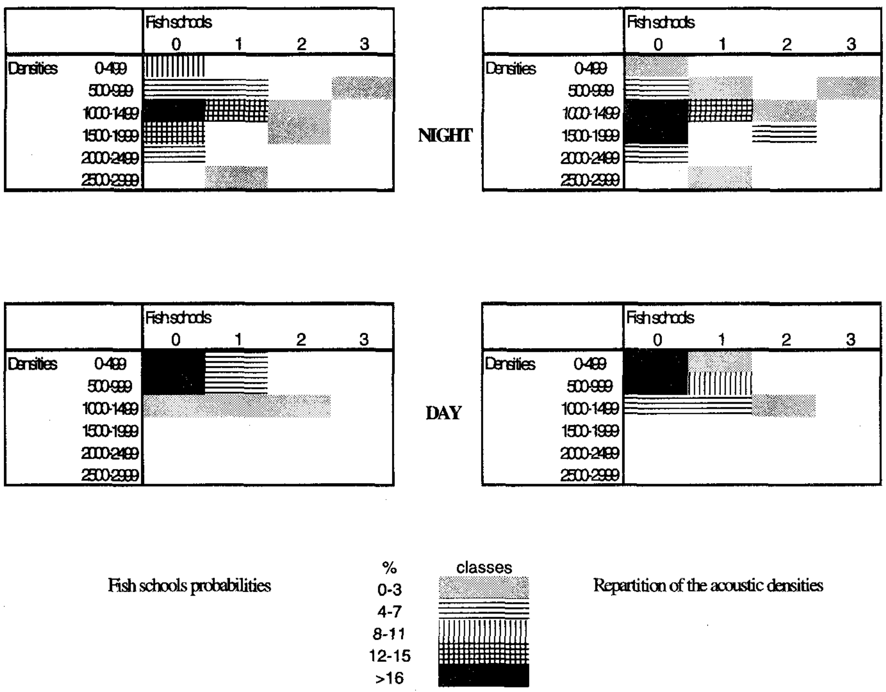


Figure 10 Results of the cross tables within the vessel cluster prospected in the South China Sea in April 1993.

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

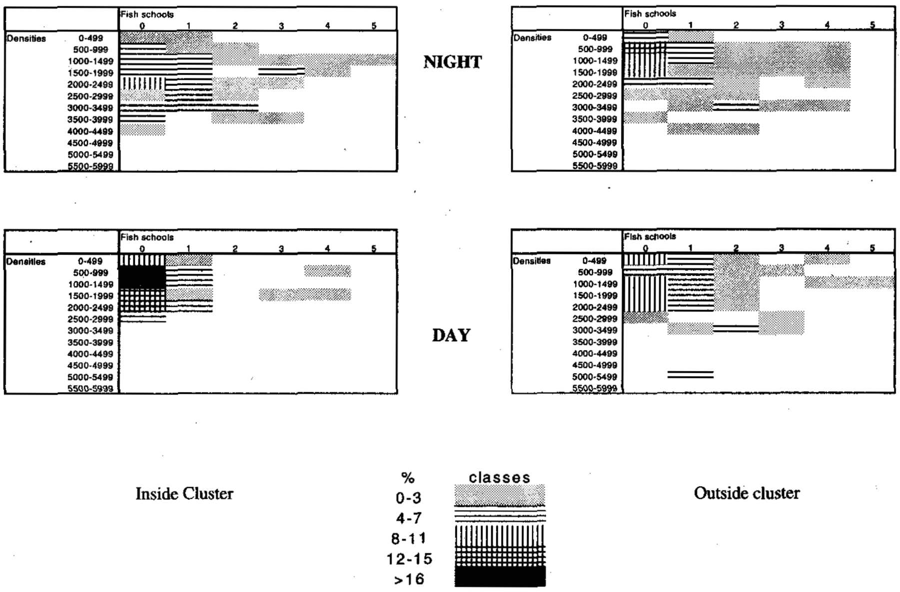


Figure 11 **Distribution of the acoustic densities (percent) expressed in UI according to the number of fish schools during the Masalembo cruise in October 1992.**

Gambar 11 **Sebaran kepadatan relatif (persen) menurut jumlah kelompok ikan pada pelayaran di Masalembo pada Oktober 1992.**

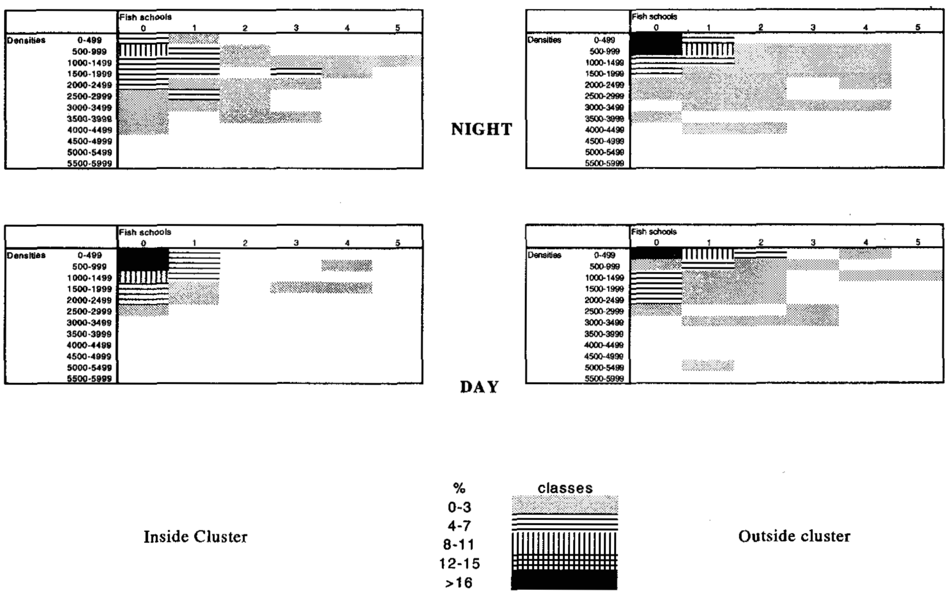


Figure12 **Distribution of the fish school probabilities according to the acoustic density classes during the Masalembo cruise in 1992.**

Gambar 12 **Sebaran peluang kelompok ikan menurut klasifikasi densitas pada pelayaran di Masalembo 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, 7,5 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

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.

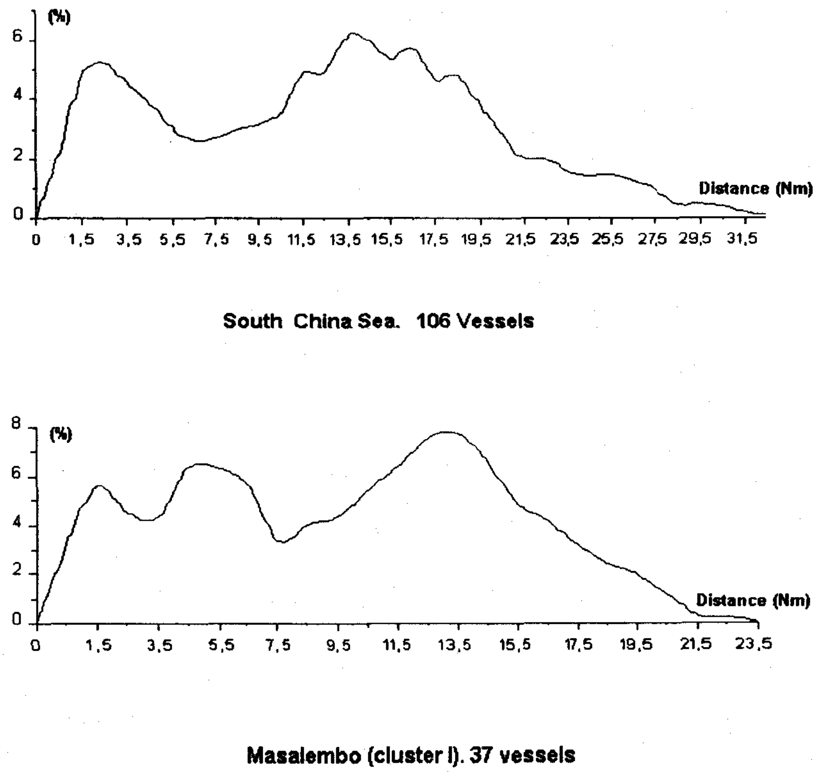


Figure 13 **Structure of the vessel clusters found during the Masalembo and South China Sea cruises.**

Gambar 13 **Struktur *cluster* kapal penangkap yang ditemukan pada pelayaran di Masalembo 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.

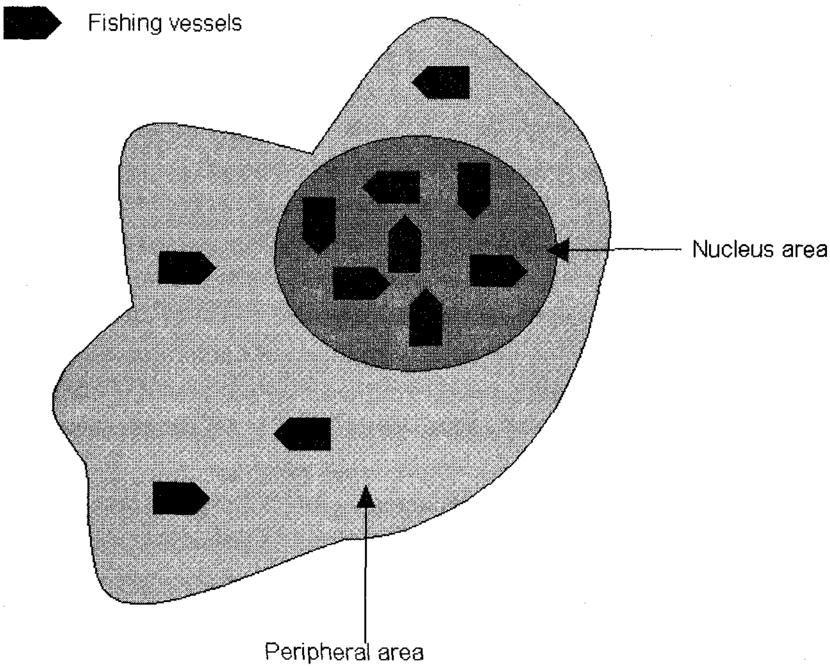


Figure 14 Structure of a vessel cluster in the Java Sea.
Gambar 14 Struktur *cluster* kapal penangkap di laut Jawa.

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.

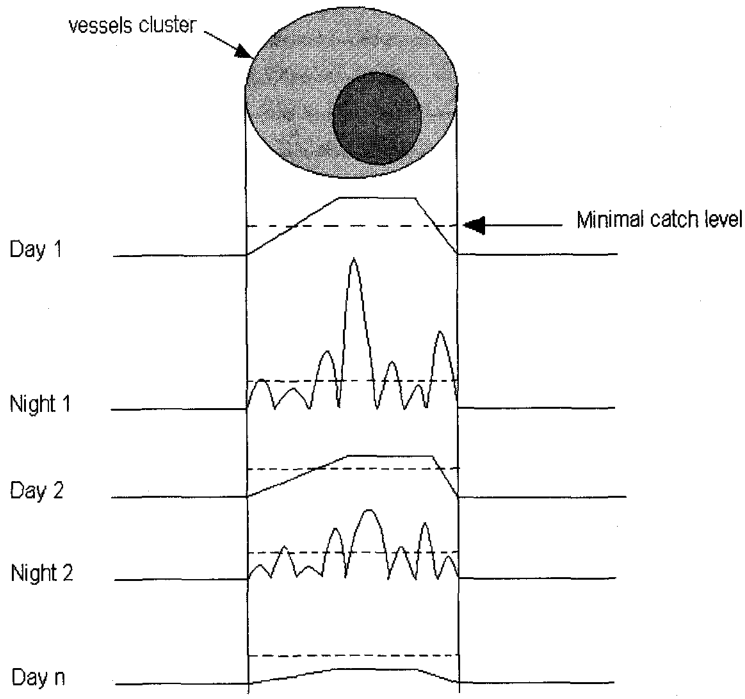


Figure 15 Scheme of the relationship between fishing vessels and the fish concentration in the small pelagic fishery of the Java Sea. Such concentration can last 4 to 6 days.

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.

DISCUSSION AND PROSPECTS

During the first part of this seminar, the results obtained and the research induced, within the frame of the PELFISH Project, have been presented; the achieved observations have been replaced in a seasonal frame linked to exploitation.

Some of the participants have regretted that the work emphasized on the East part of the basin and not on the whole area. This necessary choice has been compelled by priorities : the description of the main characteristics of the seasonal cycle by stressing on the environment of the seiners' fishing grounds.

At the regional scale, the Java Sea can be considered as a plain corridor, submitted to alternate influences of the two monsoons. A simple model, involving East-West gradients, seems to be quite enough to report the resulting movements between neritic and oceanic fauna that follow the water masses. The seasonality of the landings confirms, if necessary, this overview. Simply observing this phenomenon, measuring hydroclimatic conditions around few islands and performing seasonal acoustic surveys such as East-West transects, could provide abundance indexes. These abundance indexes could be related to climatic indexes, on the one hand, and to the regional catches, on the other hand. Taking into account the El Nino phenomenon could allow to specify its impact on the landings and on the species concerned by this climatic anomaly.

The undertaken study shows that the hydrologic dynamics is more complex than expected : there are local inter-season gradients. To go deeper in the understanding of the migratory mechanisms and the biologic cycle stages, it is necessary to sharpen the dynamic analysis of the milieu (the gradients and, above all, the currents) because the pelagic population cycle is strongly linked with.

The exploitation of the acoustic observations has been carried out in two phases. During the first one, a biological model, matching with the East-West movement of the waters, has been elaborated. The importance of the circadian cycle has been pointed up for certain species. Fishermen take profit of this cycle to optimize their catches. The strategy results from the fish distribution. The analysis of this latter, based on acoustic densities, shows the existence of a short range structure of ten nautical miles; The strongly homogeneous fish distribution gives birth to a second structure of about sixty nautical miles. The counting of the schools shows their relative scarcity; their zonation, in terms of abundance and density, is closely akin to the total acoustic density one. The convergence of the observations allows to define three acoustic populations.

During the second phase of the exploitation, some geographic sectors and new fields of study have been started on. These operations are still only at an exploratory stage; they need a deeper analysis of the already collected results and the setup of new operations.

Corroborating the first conclusions, among them the existence of coastal stratum and the progressive impoverishment to the West, the observations all along the Java coast point out local particularities, some link with the oceanic system of the East fringe and the zone facing the Sunda Strait, the richness of the bay of Semarang and a nocturnal enrichment of a bathymetric stratum situated at 35 to 40 m depth. Actually, to better describe the seasonal evolution of the Javanese basin, this latter has to be divided into nine sectors, regarding to the results, in order to improve the Java Sea modelization.

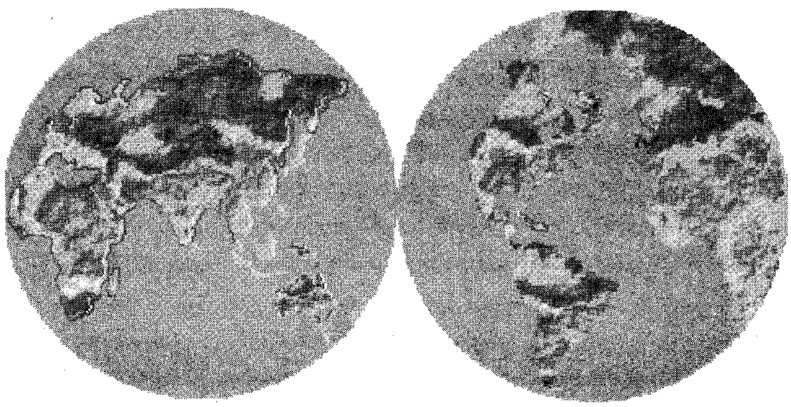
The surveys performed in the South China Sea and in the Makassar Strait as well, show that these areas deserve some attention at least seasonal, because faunas of these regions participate partially to the biological functioning of the Javanese system.

The geomorphologic conditions and the acoustic signature of the populations, met on the trip Java Sea - Natuna island in April 1993, seem to demonstrate that there is no huge bentho-pelagic stock exchange between both basins, at least concerning the adults. Nevertheless, the results of one single survey cannot allow to conclude definitely on a such important matter for fishery management. In the Makassar Strait, the first analyses focus meanly on the qualitative aspect of the populations, which match quite well with the characteristics found in the Java sea. Within this latter, the mean reverberating indexes (TS) increase from West to East. In this strait, these indexes are close to the ones found in the Java Sea. Meanwhile, we notice gradients linked with present hydrologic conditions.

All along the first part of this seminar, an important point has never been approached : the biologic sampling. Before to conclude, we would like to bring up this matter that constitutes a lack among the whole of the harvested data. During the surveys, the biological sampling attempts have failed. The insufficient catches did not allow to determine the specific composition within the different strata. For this reason, we had to rely on the commercial samplings, relatively homogeneous. These latter do not reflect necessarily the true proportion of the species in the areas. Three reasons can explain these failures : the poverty and/or the behaviour of certain species during the circadian cycle, the avoidance favoured by the smallness of the fishing gears and the low trawling speed. It is therefore primordial to overcome these failures, because the definition of strata or mean densities in these strata, even acoustically speaking, makes sense only if these species are known. The Indonesian Research has at disposal seagoing facilities with vessels able to perform experimental fishing operations (large trawls and high trawling speed). These operations would be very useful to fill the gap of information on the existence of a seasonal species zoning.

Part 2

Studies on Environment and Resources outside the Java Sea area



DIMENSION OF THE SHOALS BY ACOUSTIC METHOD AND THE POSSIBLE FISHING GEAR FOR CATCHING THE SHOALS IN THE OPEN INDIAN OCEAN

E.M. AMIN, C. NASUTION

ABSTRACT

Five acoustic surveys were carried out along the two monsoons. They took place along the West Sumatra coast, South Java coast, West of Nusa Tenggara and South of Timor. The detections were analysed until 300 m deep, by 100 m interval. The mean densities of shoals are higher in the upper layer than in the lower, but their size is smaller.

As it is impossible to identify the species by means of echo traces, these shoals have to be sampled with suitable gear : a purse seine or a pelagic trawl. The suitable dimension of a purse seine can be determinated by observation of the school size and using the formula of Fridman (1986). The sampling, with a pelagic trawl, needs an acoustic equipment to observe the fish location and the fishing gear during the catch. Different aspects and constraints are analysed which lead to consider that this technique should be used intensively in the Indonesian EEZ waters for stock assessment before commercial exploitation.

KEYWORDS : acoustics, echo integration, pelagic fish, shoals, fishing gear, Indian Ocean, Indonesia.

ABSTRAK

5 survey akustik telah dilaksanakan selama 2 musim di wilayah barat Sumatera, selatan Jawa hingga Nusa Tenggara dan selatan Timor. Analisis perekaman dilakukan hingga kedalaman 300 m dengan selang 100 m. Rata-rata kepadatan kelompok ikan cenderung tinggi pada lapisan permukaan dengan besar ukuran yang cenderung lebih kecil dibandingkan pada lapisan perairan yang lebih dalam.

Dengan keterbatasan proses identifikasi jenis cercah gema maupun kelompok ikan yang terekam pada saat penelitian, kelompok ikan tersebut harus ditangkap dengan bantuan alat yang sesuai yaitu pukat cincin atau trawl pelagis. Dimensi alat yang sesuai dapat diturunkan dengan menggunakan persamaan yang dikemukakan oleh Fridman (1986). Penangkapan dengan trawl pelagis memerlukan perangkat akustik sebagai sarana pengamatan keberadaan ikan. Beberapa aspek yang berkaitan serta keterbatasannya dibahas dalam tulisan ini sebagai dasar pertimbangan penggunaan teknik ini dalam pengkajian sediaan secara intensif di kawasan Zona Ekonomi Eksklusif sebelum dilakukan pemanfaatan secara komersial.

KATA KUNCI : akustik, echo-integrasi, ikan pelagis, kelompok ikan, alat tangkap, Samudera Hindia, Indonesia.

In general, the Indonesian waters can be divided into several parts : the shallow Sunda Shelf in the West, the Sahul Shelf in the East, the deep ocean in the South and the deep seas, straits and channels in the middle part. The economic and social development will depend on the exploitation of natural resource of these waters. It is imperative for Indonesia to concentrate its activity on the exploitation of its marine resources. This activity can be conducted only if the basic data of its own resources are available. Indonesia's marine fishery resources are evenly exploited, and some fishing grounds are under heavy pressure, with a level of fishing effort greater than necessary to achieve maximum sustainable yield. In other areas, such as EEZ waters of Indian Ocean, available stocks are underexploited and could support expended fishing effort and larger harvest. The annual potential yield of EEZ waters, extending from the West of Sumatra to the South of Timor, has been estimated by the acoustic method, within the depth of 300 m, in the area of 757,400 km^2. The result was a value of 455 - 680 thousand tons (Amin *et al.*, 1992). DGF (1994) stated that pelagic fish production, from Bengkulu Province to Timor-Timor Province, was 180,312 tons.

It is evident that the potential yield of Indian Ocean EEZ waters has been exploited less than 40% and still have good opportunity for increasing the exploitation level. To exploit these fish resources, the suitable fishing gears are needed, depending on the fish resource characteristics.

MATERIAL AND METHODS

Research by using acoustic method had been conducted in :

- EEZ waters in West Sumatra (Bengkulu - Lampung), covering an area of 205,794 km^2, on July 1990 (SE Monsoon) and March-April 1991 (NW Monsoon),
- EEZ waters in South of Java, covering an area of 385,900 km^2, on March 1990 (NW Monsoon) and August 1990 (SE Monsoon),
- EEZ waters in South of Timor, covering an area of 165,700 km^2 on August-September 1991 (SE Monsoon).

This research was conducted by the Research Vessel (R/V) Baruna Jaya I, whose characteristics are shown in Table 1. The vessel was equipped with an echo-sounder SIMRAD EK 400 - Model AR 800a/38 kHz and oceanographic instruments, but without fishing gear for sampling. The control settings, normally used on the sounder during the cruises, are listed in Table 2.

Table 1 The main specification of R/V Baruna Jaya I.
Tabel 1 Spesifikasi utama dari armada R/V Baruna Jaya I.

LOA	60.4 m	Gross Tonnage	700 metric tons
Breadth	11.6 m	Displacement	1,200 tons
Draft	4.5 m	Main Engine	2 (285 HP)

Table 2 Control settings of echosounder.
Tabel 2 Kontrol seting dari echosounder.

Depth interval	0-300 m	Paper speed	7.3 mm/min
Output power	1/1	Pulse repetition	30 ping/min
Bandwidth	3.3 kHz	Pulse duration	0.6 ms
TVG	20 log R	Sub gain	1
Recorder gain	3		

Because of incomplete fishery research instruments (there was no integrator), the analysis has been performed from echogram observation which is the simplest and the easiest way, in acoustic method, for finding data, such as : number of shoal (n), density (Dn), height (h) and diameter (dc). They are calculated by using the formulas of Forbes and Nakken (1972), Johannesson and Losse (1973) and Bazigos (1981) with the assumption that the fish shoals are equivalent to a cylinder.

$$D_n = \frac{n}{L \times 2\,tg\frac{1}{2}\alpha D_h}$$

$$d_c = \frac{4}{\pi}\left[\frac{lv}{c} - 2\,tg\frac{1}{2}\alpha\, D_m\right]$$

where :

Dn	: density of shoal
n	: number of shoals along the track
L	: length of track
Dh	: half of depth of detection
dc	: diameter of shoal
l	: length of the trace on the paper
v	: vessel speed
c	: paper speed
Dm	: mean deep of shoal
α	: beam angle

RESULT AND DISCUSSION

Shoal dimension

Five acoustic surveys were carried out in North-West (NW) and South-East (SE) monsoon for the sub areas of West Sumatra and from the South of Java, to the West of Nusa Tenggara and one cruise took place during South East monsoon, in South of Timor Island. The survey area is shown in Figure 1. The observations were made until 300 m deep, by 100 m intervals.

Echo trace analysis shows that there are some spatial and temporal differences in shoal density (n/km^2). Generally, the mean densities in the upper layer were higher than the ones in the lower layer, while the mean dimension of the shoals in the upper layer was smaller than the one in the lower layer (Tab. 3, 4 and 5).

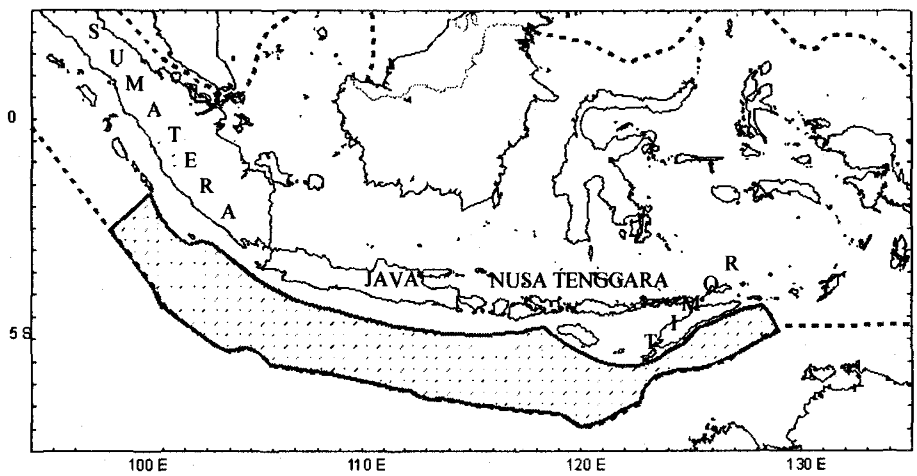


Figure 1 The survey area.
Gambar 1 Daerah survey.

Table 3 Shoal density and shoal dimension in EEZ of West Sumatra.
Tabel 3 Kepadatan dan dimensi dari kelompok ikan di Zona Ekonomi Eksklusif, Sumatra Barat.

Depth (m)	0-100			101-200			201-300		
Monsoon	NW	SE	Mean	NW	SE	Mean	NW	SE	Mean
Number of shoal (n)	48	44		37	81		9	46	
Sampling area (km²)	38.3	51.3		115	153.8		191.7	256.4	
Density (n/km²)	1.25	0.86	1.03	0.32	0.53	0.44	0.05	0.18	0.12
Diameter (m)	70.3	74.4	72.4	64.3	88.2	80.7	49.8	123.2	111.2
Height (m)	6.4	9.8	6.7	4.8	13.4	10.7	6.5	19.1	17.0
Depth of shoal (m)	59	68	63	139	148	145	234	247	245

Table 4 Shoal density and shoal dimension in EEZ of South Java.
Tabel 4 Kepadatan dan dimensi dari kelompok ikan di Zona Ekonomi Eksklusif, Samudra Hindia, Selatan Jawa.

Depth (m)	0-100			101-200			201-300		
Monsoon	NW	SE	Mean	NW	SE	Mean	NW	SE	Mean
Number of shoal (n)	53	99		29	41		19	82	
Sampling area (km²)	41.3	53.8		128.3	167.3		213.8	278.9	
Density (n/km²)	1.28	1.84	1.60	0.23	0.25	0.24	0.09	0.29	0.21
Diameter (m)	86	69	75	98	56	73	74	65	67
Height (m)	13	11	12	11	8	9	17	20	19
Depth of shoal (m)	67	54	59	156	157	157	262	252	254

Table 5 Shoal density and shoal dimension in EEZ of south of Timor during South East Monsoon.
Tabel 5 Kepadatan dan dimensi dari kelompok ikan di Zona Ekonomi Eksklusif di selatan Timor selama musim kemarau.

Depth (m)	0-100	101-200	201-300
Number of shoal (n)	27	20	18
Sampling area (km²)	33.2	99.8	170.2
Density (n/km²)	0.8	0.2	0.1
Diameter (m)	81	94	70
Height (m)	13	12	17
Depth of shoal (m)	60	168	234

Possible fishing gear for catching fish shoals

There is no general rule which allows a group of fish to be identified directly from its echo trace. This is because there is no species of fish constant enough in its behaviour to give, at any time, the same echo pattern. Since different species of fish exhibit similar patterns of distribution behaviour, they will give rise to similar echo records.

One obvious method for identification used in association with echo-survey, is sampling with appropriate catching gear. Unfortunately, the method could not be used due to the fact that R/V Baruna Jaya I was not equipped with fishing gear and constructed for oceanographic purposes.

The fish concentrations occurred in the layer of 0-150 m depth, were mostly recorded as smooth-faced echo trace and assumed as small pelagic fish shoals. These fish concentrations could be caught by purse seine and midwater trawl.

Purse seine

Purse seine has been used to exploit the pelagic stock in Indonesian waters. The design of the adapted gear is dependent on the depth of fishing, the sinking speed, shrinkage, buoyancy of the float and float line, sinking force of the sinker line, mesh size and purse line. One of the most important factors is the length of net, because there are relationships with the vessel size, the dimension of the fish shoal and the fishing tactic. There are 3 groups of fishing tactics :

a) searching and scouting fish shoal
b) light fishing without *rumpon*
c) fishing with *rumpon*.

The length of the net (L) could be calculated by using the formula of Fridman (1986) :

- for fishing with a *rumpon* or with light without *rumpon* :

$$L_{min} = 2\pi(a + r_s)$$

- for fishing by searching and scouting the shoal :

$$L_{min} = b(a + r_s)$$

where,

a = the shortest distance between the vessel and the shoal without disturbance of the shoal. This coefficient is dependent of the speed of fish swimming (and sinking), Vs and the time of the net sinking Ts, or equivalent to Vf/Ts.

b = a seine length coefficient, function of the net setting and the speed of shoal swimming.

r_s = 0.5 time the shoal diameter.

Swimming speeds of fish shoals are evaluated as 1.1 (in m/sec) for sardine, 1.3 for mackerel, 1.6 for skipjack. So, we can adopt a mean speed of 1.3 m/sec. At a vessel speed of 8.5 knots, b can be evaluated as 9.5. With a shoal diameter of 75 m (as in Tab. 3, 4, 5), the r_s would be 37.5 meter.

Therefore, for searching and scouting, a = 50-100 m, and for using rumpon and lighting, a = 20-30 m.

Based on those data, the minimum length of purse seine in the survey area is :

- for using *rumpon* and lighting purpose :

$$L_{min} = 2\pi \text{ x } (20 + 37.5) \text{ m} = 400 \text{ m}$$

- for searching and scouting purpose :

$$L_{min} = 9.5 \text{ x } (50 + 37.5) \text{ m} = 850 \text{ m}$$

Pelagic or midwater trawl

The subsurface or midwater fish concentrations (schools or aggregations), occurring either in epipelagic or mesopelagic zones of the open ocean, could also be caught by pelagic or midwater trawls, sometimes called floating trawls. The term of "pelagic" is preferred rather than "midwater" for the gears, trawling the pelagic fish concentrations in the pelagic zones of the open ocean.

A fundamental feature of the pelagic trawling is that the zone of operation extends over the hole water column. The gear must work at different depths, according to the particular deep distribution of the fish. This varies widely, in space and time. Therefore, pelagic trawling would almost be impossible without the use of detecting devices, such as fish detecting and net detecting devices (Parrish, 1962; Brandt, 1972). The use of echo-sounder, for detecting the depth of fish concentrations, and the netsonde to control the depth of the fishing gear, has become the prerequisite in the pelagic trawling.

a. Type of pelagic trawl

The pelagic trawls can be divided into 2 types of operational category, *i.e.*, trawls towed by 2 boats (called the two-boat pelagic trawls or pelagic pair trawls), and trawls towed by a single boat, or one-boat pelagic trawls. Figure 2 and 3 show the illustration of the two-boat and the one-boat pelagic trawls.

In the two-boat pelagic trawl, the warps spread out the net horizontally. The otter boards are not needed, so there is nothing in front of the net to frighten the fish. However, this pelagic trawl is faced by the difficulty in manoeuvring two boats, side by side, at a certain distance from each other and at the same speed, particularly in bad weather. It seems impossible for two large trawlers to fish together. Two-boat pelagic trawling is restricted to small and medium size boats (Brandt, 1972).

In the one-boat pelagic trawl, otter boards spread out the net horizontally. The noises of propeller, otter boards and warps are supposed to frighten the fish away from the net mouth. Though it sounds reasonable, the many good catches, made with one-boat pelagic trawls, have demonstrated that it must not always be true. The one-boat pelagic trawling can be carried out by larger boats, which can also fish in greater depths, on more distant grounds and for other fish species (Brandt, 1972).

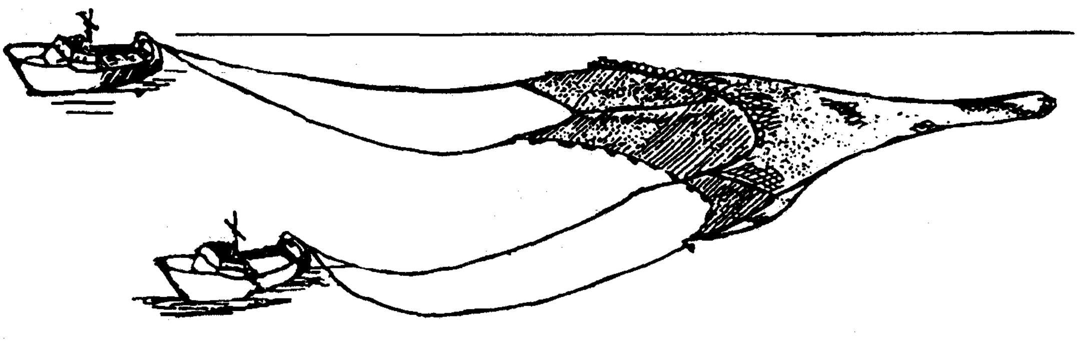


Figure 2 The illustration of the two-boat pelagic trawling.
Gambar 2 Ilustrasi trawl pelagis 2 kapal (sumber : Garner).

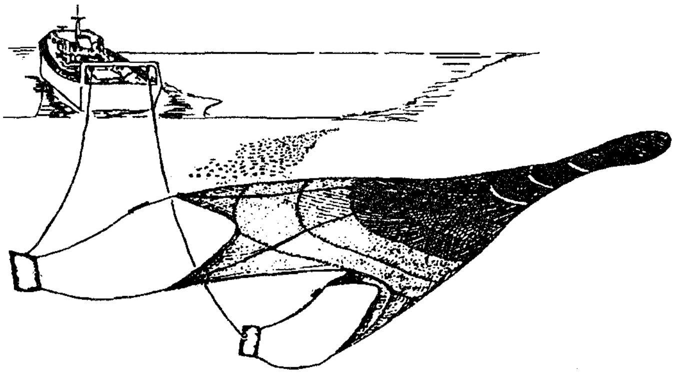


Figure 3 The illustration of the one-boat pelagic trawling.
Gambar 3 Ilustrasi trawl pelagis 1 kapal (sumber : Garner).

b. Net and its rigging

- Net design

There are two basic patterns of pelagic trawl net, *i.e.,* two-seam net and four-seam or four-panel net (Parrish, 1962; Brandt, 1972; Garner). Though not always, it appeared that the four-seam net is preferred for one-boat pelagic trawls, while the two-seam net for two-boat pelagic trawls. The two-seam net is restricted vertically, whereas the four-seam net has a great vertical opening due to the side panels (Parrish, 1962).

Parrish (1962) underlined the general features in designing pelagic trawl net. The net, with a large vertical and horizontal of a square or rectangular mouth opening, corresponds to the vertical and horizontal distribution of the fish concentrations.

- Mesh size and net twines

The pelagic trawl nets are very large and consequently subject to large drag factors. To minimise this drawback the meshes in the frontal area (wings and square) are comparatively large, and the panels down the body decreased proportionately to meet the cod end with mesh size suitable for catching a specific fish species.

The pelagic trawls should have a low resistance when towed, and the water flow through the trawl must be good. It can be achieved, with the use of netting yarns of small diameter. The high resistance synthetic twines are considered as one of the prerequisites for pelagic trawls. Netting yarns for pelagic trawls should have particularly high extension and elasticity, beside high wet-knot breaking strength at smallest possible twine. Twisted netting yarns are preferred for pelagic trawls (Brandt and Klust, 1971). The use of nylon or polyamide twines has been found to be the most suitable for pelagic trawls (Garner *in* : Brandt, 1972), instead of polyethylene materials convenient for bottom trawls.

Garner presented an example of the relationship between mesh size and twine size of a one-boat pelagic trawl net for 1,000/1,200 HP trawlers, as follows : the meshes and twines range from 800 mm of 210/180 in the wings, and down to 400 mm of 210/96, 200 mm of 210/96, 100 mm of 210/48, and 30 mm of 210/72 in the cod end.

- Strengthening ropes

Most designs of pelagic trawl are voluminous, comparatively weak and susceptible to sudden load factors. To counteract this, pelagic trawls must be strengthened far more than the ordinary bottom trawls. In addition to headline, foot-rope and side ropes, pelagic trawls are provided with a frame work of strengthening or support ropes, along with the stresses are carried and transferred to the main towing ropes (Garner). The principal strengthening ropes are those attached along the seams of the net. These ropes or "seaming ropes," are normally heavier than the other support ropes for they have to be strong enough to carry a large percentage of the load directly to the towing bridles.

- Sheering devices

The openings of pelagic trawl nets, in the most effective form, are kept by a number of weights on the foot-rope at the lower wing tips and the front weights, as well as otter boards. The force, needed to open the net vertically, is particularly induced by the weights, at the lower wing tips. The opening is not only upwards but also downwards (Brandt, 1971).

Floats have constant buoyancy but the inherent disadvantage of increasing towing resistance with increasing towing speed. Replacing floats and weights with hydrodynamic elevators and depressors, the sheer of which changes with speed, same as resistance, was an effort to avoid the inherent disadvantage (Brandt and Klust, 1971).

- Otter boards

The otter boards or doors are fundamental for the efficiency of the trawling assembly as a whole, particularly in one-boat pelagic trawl. Otter boards, for pelagic trawl, are those creating little or no turbulence, having no downward shear and acting only in horizontal, or even in slightly upward direction. The turbulence can be avoided by choosing short upper and lower edges and by using curved profiles instead of a plane. The hydrofoil otter boards are suitable for pelagic trawls.

c. Towing speed

The towing speed regulates the fishing depth and the vertical opening of the net. Increase in towing speed leads to decrease the vertical opening. Kodera (1971) suggested towing speed of 4.0 to 4.5 knots to have an opening as high and wide as possible. The towing speed is not decisive for large trawls and a reduction to about 2 knots is sometimes even favourable, because then the turbulence decreases and the fish may be outwitted (Brandt and Klust, 1971).

The towing speed may influence the escape distance between fishes and netting. It seems that decrease in towing speed resulting in decrease in the escape distance (Brandt and Klust, 1971). For catching large fast-swimming fish in quantity, extremely large nets pulled at relatively low speed are more effective than smaller nets pulled at higher speed (Brandt and Klust, 1971).

d. Favourable conditions for pelagic trawls

The pelagic trawling encounters the pelagic fish with their own specific features. Most pelagic fish are active and/or fast swimmers, and probably react quickly and more violently to the stimuli. They usually form compact schools, mainly during daylight, and respond as a body to disturbance stimuli. They have well-developed organs of sight and hearing, which may also facilitate their avoidance in front of the gear, particularly in daylight when the warps, otter boards and the net will be seen more easily. The high temperature of the upper water layers tends to increase their activities and hence stimulate their avoidance ability.

The behaviour of pelagic fish probably governs the effectiveness of pelagic trawls to a critical degree and also influences the design, rigging and operation of the net. Parrish (1962) underlined the most probably favourable conditions for the pelagic trawling. The fish concentrations should be fairly large and remain approximately stationary. The fish have to be relatively inactive, either by virtue of low water temperatures, or their physiological state (in general, spawning and spent fish are probably less active than the feeders). The fish do not undergo rapid diurnal depth migrations, and their depth distribution is fairly constant over the fishing locality. The water must be shallow and turbid or, if clear, contain low concentration of phosphorescent organisms. The light intensity has to be low. In spite of some conditions not favourable, trawling might certainly be successful, particularly when the fish concentrations are considerably large and dense, and when large pelagic trawls are towed at high speed, by powerful boats.

Though, in the beginning, pelagic trawlings were carried out during the night when the herrings are found at 18 to 56 m depth, depending on weather conditions and darkness, more and more trawlings now take place in daylight when the herrings are usually found from 92 to 148 m depth. Thus, those fish concentrations in the epipelagic and mesopelagic zones of the open ocean, traced through acoustic surveys, will obviously be an essential asset for near in future to be exploited.

CONCLUSION AND RECOMMENDATION

- EEZ waters of Indian Ocean extending from the West of Sumatra to the South of Timor in the area of 757, 400 km^2 were estimated by acoustic method to have 1.3 shoals/km^2 in the layer from surface to 100 m depth.
- The mean diameter of the shoal is 75 m and could be caught by purse seine and midwater trawl.
- The length of the purse seine is :
  - Purse seine operated by using rumpon and lighting : 400 m
  - Purse seine operated by searching and scouting : 850 m
- The midwater trawl :
  - Further experiments on the one-boat pelagic trawling are recommended to ascertain the potential of the fish concentrations in the Indonesian EEZ waters before introducing it to the commercial fisheries.

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Discussion

(Chairman Dr. Marchal)

Dr. Pasaribu

Q : - Have all these surveys been carried out with the R/V Baruna Jaya and the use of the echo-sounder EK400 ?

A : - Yes, but these surveys were multi-disciplinary cruises for oceanographic purpose. Many hydrographic stations have been performed.

Dr. Pasaribu comments : "I guess how difficult it can be to calculate the diameter of schools. Many problems may occur if you use this formula to find the mean diameter. The calibration of the echo-sounder to evaluate its sensitivity can be one source of worry. Echograms do not represent the actual fish schools, especially the lower part where we have a lack of information. The third problem could be the fish school pattern which is so variable that talking about mean diameter cannot be assumed. Anyway, these data can be used as statistical data to make rough prediction."

A : - I do not understand your difficulty to estimate the diameter. Our sounder has a TVG (Time Varied Gain). Our aim was to study schools only, disregard the other studies like Target Strength measurement, etc. First, we defined the borders of the schools whose limits are obvious. It is assumed that schools have cylindrical shapes. We applied then this assumption and calculate the diameters. There are, of course, many corrections applied to depth calculation, etc. Paper speed and vessel speed have been also taken into consideration.

Dr. Marchal

Q : - Is there any sonar on the R/V Baruna Jaya ?

A : - There is only one side scan sonar for hydrography, but none for fishery. If we could use such a sonar, we would chase schools with midwater trawl. The information could be completed with its netzond.

Dr. Merta

Q : - You have performed surveys in almost all areas, but not in the South of the Java Sea. What were your reasons to do such cruises ?

A : - These cruise tracks were decided by LIPI and at this moment, the sea was very rough and we adapted the trip to the weather conditions.

Dr. Merta comments : "You presented the density per square nautical mile and it seems that the size of the schools is very variable; it would be good to stratify this density, let us say : for the larger ones such density, for the smaller ones such density, etc."

IN SITU MEASUREMENT OF FISH TARGET STRENGTH BY SPLIT BEAM ACOUSTIC SYSTEM

C. NAINGGOLAN, B.P. PASARIBU

ABSTRACT

The Split Beam acoustic system makes possible to determine the exact location of a target. This feature is useful to compensate returned echoes from beam pattern effect, when measuring fish Target Strength.

In this experiment, the parallel data output of an ES 470 Split Beam echo-sounder sounder was connected to a personal computer to collect acoustical data. This configuration was applied to gather acoustical data from a stainless steel sphere and also data from free swimming fish in the Tateyama Bay, Japan.

The "best fit" equation to represent measured beam pattern and the Target Strengths of free swimming fish are presented.

KEYWORDS : acoustics, Split Beam, Target Strength, methodology, anchovy, Pacific Ocean.

ABSTRAK

Sistem akustik split bim memungkinkan untuk menentukan posisi ikan. Hal ini merupakan suatu keunggulan dan sangat bermanfaat untuk mengkompensasikan gema balik dari pengaruh beam pattern dalam pengukuran ukuran (Target Strength) ikan.

Pada percobaan ini, paralel data yang dihasilkan pada echo-sounder ES 470 spit beam yang dihubungkan dengan komputer sebagai sarana untuk mengumpulkan data akustik. Konfigurasi ini diterapkan untuk mengumpulkan data stainless steel sphere serta data ikan di perairan Teluk Tateyama, Jepang.

Kecocokan persamaan untuk menggambarkan beam pattern dan besar ukuran ikan yang terdeteksi disajikan dalam tulisan ini.

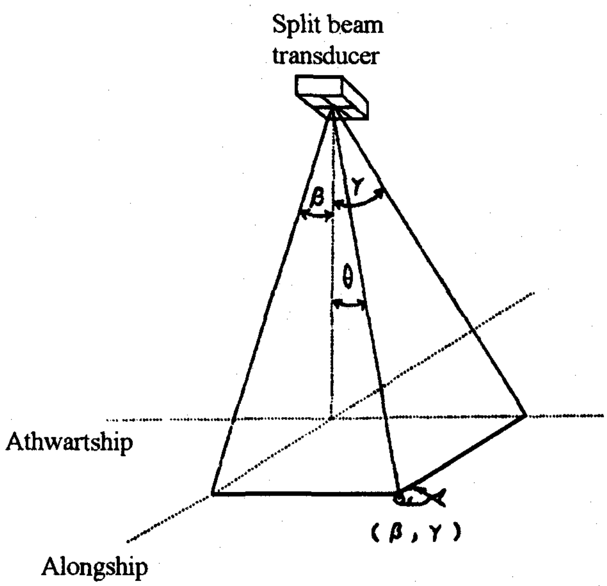
KATA KUNCI : akustik, Split Beam, Target Strength, metodologi, anchovy, Samudera Pasifik.

Recently, the quantitative assessment of fish stock has become increasingly important, due to the sustainable resource management. The earlier method to estimate fish abundance, using echo-sounder, was relied upon counting the echoes of individual fish recorded on the echogram. Unfortunately, the fish are often concentrated in schools that are often too dense for discriminating single fishes. The limitation of counting method is overcome by the alternative method of echo-integration which integrates the echoes of fish school to obtain the so-called "volume back Scattering Strength" (SV) of the school. The SV of fish school is scaled by the Target Strength (TS) of single fish to obtain density of fish in the school. As the TS is used to scale the SV, the accuracy of the estimation depends on precise measurement of TS.

The conventional echo-sounder with its traditional transducer can not measure fish Target Strength *in situ*, because it can not determine the location of fish in the sound beam. The returned echo from fish can not be compensated for the beam pattern effect of the transducer. Thus, the returned echo gives ambiguous result of the Target Strength value. This ambiguity is due to the fact that the same signal may come from a small fish on the acoustic axis of the transducer or from a large fish, near the edge of sound beam.

At present, there are 2 kinds of advanced transducers which can compensate the beam pattern effect, namely Dual-Beam and Split Beam. Dual-Beam echo-sounder uses two coaxial transducers, having different beam shapes (Ehrenberg, 1983). The transmission is done on the narrow beam, while the reception is done both on the narrow and the wide beams. Comparing the echoes from the two receivers, the beam pattern on the detection angle can be found and removed from the returned echoes.

The Split Beam echo-sounder uses a transducer which is divided into four quadrants (Foote *et al.*, 1984). Information on the position of the fish in the sound beam is given by the phase difference between the echo signals received by two transducer halves. When Split Beam echo-sounder detects fish, the information about the fish location in the sound beam is also presented (Figure 1 illustrates relative location of fish in the sound beam of the transducer). Knowing the location of fish in the sound beam and its direction then deduced, it is possible to perform compensation for the variation in sensitivity of transducer, and resulting, the Target Strength value of fish measured *in situ*.



$$\theta = \tan^{-1}\sqrt{\tan^2\beta + \tan^2\gamma}$$

Figure 1 Geometric view of the direction of the target.
Gambar 1 Penampilan geometrik arah sasaran.

This paper describes an experiment to measure the Target Strength of fish *in situ* with a Split Beam echo-sounder. The purpose of this experiment is to measure the beam pattern and single fish Target Strength values, using parallel output channel facility provided in the Split Beam echo-sounder.

MATERIALS AND METHODS

Split Beam echo-sounder

For this experiment, the ES 470 (70 kHz) installed on the research and training vessel Seiyo Maru, from the Tokyo University of Fisheries, was used to collect acoustical data. For data logging, the real time parallel data output of the echo-sounder was linked to a personal computer. The data obtained are : depth, uncompensated signal amplitude, longitudinal (alongship) and transversal (athwarthship) angle of the detected target.

The depth resolution is 10 cm, and the signal amplitude value is in binary number from 0 to 4095, corresponding to the output from a 12 bit analog to digital converter. The maximum binary value corresponds to 2 Volts. The angle values are logged in, from -63 to +63, with an angular resolution of 0,14 degrees.

During the experiments, the echo-sounder was set with a pulse duration of 1 ms and the display range used was 50 m (for calibration and single fish Target Strength measurement). The ping rate was 110 sounding per minute.

Data collection

Before measuring fish Target Strength, the echo-sounder was calibrated, using a stainless steel sphere (diameter = 35.4 mm, TS = -39.9 dB). The sphere was suspended, using a pair of fishing rods, below the transducer in the sound beam, at a depth between 10 to 13 m (fig. 2). The sphere was pulled through the beam in several cross sections, and the acoustic data from the sphere were recorded onto a floppy disk.

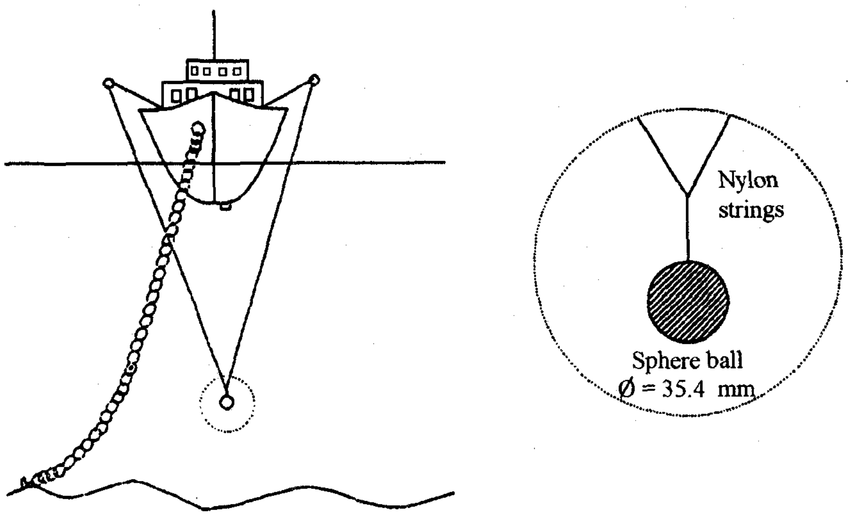


Figure 2 The sphere suspended below transducer.
Gambar 2 Sphere digantungkan di bawah transducer.

Target Strength measurements of free swimming fish were carried out in the Tateyama Bay, at about 100 km from Tokyo, in the South. During data collection, the vessel speed was 5 knots. All the acoustic data on fish were recorded on floppy disk for further analysis.

For gathering and analyzing the acoustic data, a special program was made to handle the flow of data from the echo-sounder to a personal computer. On the basis of recorded data, the beam pattern of transducer and Target Strength of detected single fish were measured.

Beam pattern measurement

The sphere was successfully guided through 3 cross sections of the sound beam. To process the recorded data from the sphere, a program routine was written, which searched downwards in sounding data until it found a sample with a signal amplitude above a chosen threshold. In this case, the threshold was set to 100 mV. Table 1 shows the sample of sphere data, during beam pattern measurement. The group of data, enclosed in the box, concerns the sphere. In this case, the depth of the sunk sphere would be 10.9 m. The pair of angles corresponding to the depth and the following 6 samples were processed as follows :

Table 1 Split Beam echo-sounder output data. The group of data, enclosed in the box, concerns the data of the sphere.

Tabel 1 Keluaran data echo-sounder Split Beam. Data merupakan hasil pengukuran *sphere*.

Depth (m)	Amplitude (Volt)	Alongship (°)	Athwarship (°)
...	...	...	...
...	...	...	...
10.1	0.027	0.70	3.08
10.2	0.035	2.52	3.78
10.3	0.041	4.34	4.06
10.4	0.037	3.36	4.62
10.5	0.035	2.66	3.92
10.6	0.035	1.26	2.66
10.7	0.043	2.38	-0.70
10.8	0.035	2.66	-0.56
10.9*	0.183	-2.80	-0.14
11.0	0.248	-2.94	-0.28
11.1	0.280	-2.80	-0.28*
11.2	0.300	-2.94	-0.28
11.3	0.308	-2.80*	0.28
11.4	0.317*	-2.80	-0.42
11.5	0.248	-2.94	-0.56
11.6	0.097	-3.22	-0.98
11.7	0.052	-4.32	-0.62
11.8	0.047	-4.48	-0.84
11.9	0.025	-4.20	-4.62
12.0	0.022	-2.80	-1.12
...	...	...	...
...	...	...	...

The 3 highest and the 3 lowest values of alongship and athwartship angles are omitted. The remaining values of alongship and athwartship angles give the coordinate position of target in particular sounding. The echo amplitude is the maximum amplitude sampled within the echoes. The data in the frame show the depth of the sphere which was 10.9 m, the amplitude of echo : 0.317 mV, the alongship angle : -2.80°, and the athwartship angle : -0.28°.

The sphere amplitude values, from the different soundings, were plotted against the relative angle of the target to the axis of transducer, giving the transducer beam pattern in corresponding cross section (fig. 3, 4, 5). To get the decibel value of amplitude in the plotting, the amplitude reading of the sphere in the center axis of transducer (at position 0.0) was used as reference for each value.

The "best fit" equation for the beam pattern is :

$$B = 0.463\,\theta^2 \qquad (1)$$

$$\theta = \tan^{-1}\sqrt{\tan^2\beta + \tan^2\gamma} \qquad (2)$$

where :

B : two-way beam pattern correction,
β : alongship angle of the target (degree),
γ : arthwartship angle of the target (degree).

1.4 Single fish Target Strength measurement

The experiment for measuring fish Target Strength was carried out in the coastal waters of Tateyama Bay. The acoustic data of fish were collected and recorded along a 12.5 mile parallel grid vessel's track. In addition to the acoustic data, fish samples were also taken from the local fishermen operating purse seine net in the bay, at the day of experiment.

The extraction of single fish echoes from the recorded data, is done by the program searching downwards until it finds a sample with a signal amplitude above a chosen threshold; the threshold was set to 23 mV. The search was applied, in a similar fashion, to the beam pattern measurement. Figure 6 shows a typical shape of echo, from a single fish detected by the echo-sounder. In addition to this vertical search, there was also an horizontal search to determine the number of successive soundings of fish detected by the echo-sounder, when fish passed across the acoustic beam. If the search program found the signal of a single fish, the maximum amplitude value was chosen to represent the amplitude of fish.

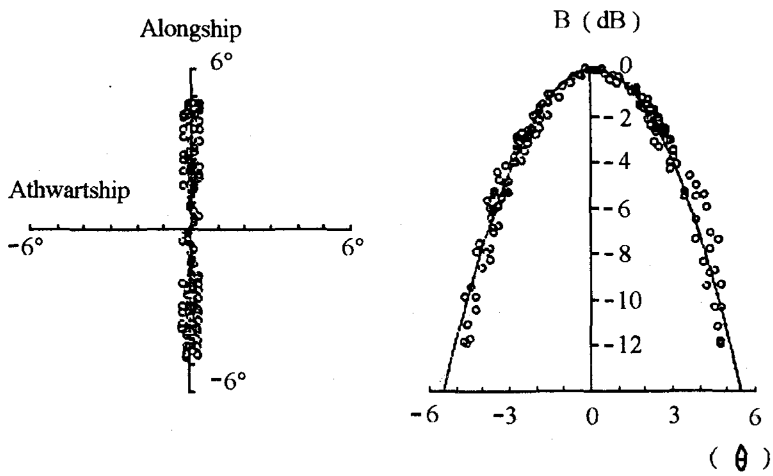


Figure 3 Plotting of the sphere and lobe diagrams in the first cross section.
Gambar 3 Diagram penampang 1 melintang *sphere* dan *lobe*.

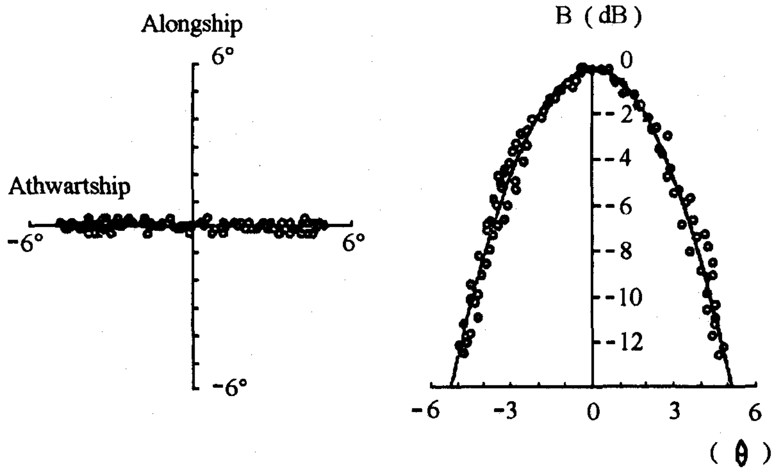


Figure 4 **Plotting of the sphere and lobe diagrams in the second cross section.**
Gambar 4 **Diagram penampang 2 melintang *sphere* dan *lobe*.**

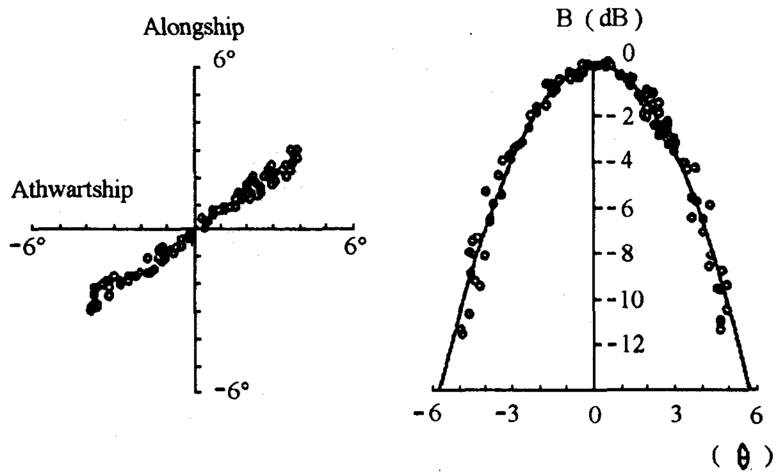


Figure 5 **Plotting of the sphere and lobe diagrams in the third cross section.**
Gambar 5 **Diagram penampang 3 melintang *sphere* dan *lobe*.**

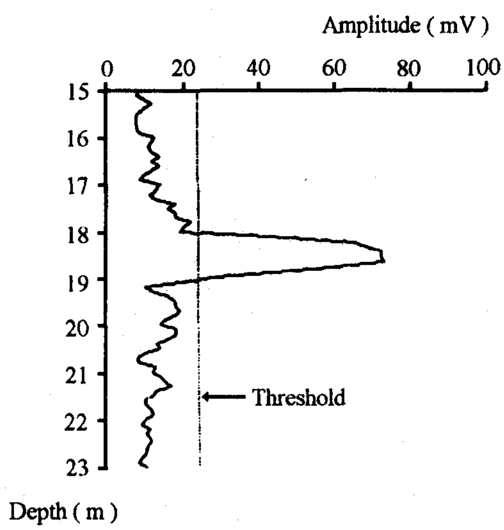


Figure 6 **Typical shape of single fish echo.**
Gambar 6 **Bentuk gema ikan tunggal.**

The formula to calculate fish Target Strength is given below :

$$TS = 20 \log U - SL - VRc + TVGc + B \quad (3)$$

where :

U	: maximum amplitude of fish (Volt),
SL	: source level (dB),
VRc	: receiving voltage response at maximum TVG range (dB),
TVGc	: echo-sounder Time Varied Gain constant (dB),
B	: Beam Pattern Factor.

RESULTS

Beam pattern

The tracking of a sphere through the beam, in various cross sections, shows that the sphere disappeared, at about 5 degrees from center axis of the transducer, corresponding to 10 degrees circular beam. The lobe diagrams, obtained in various cross sections of the beam, and the equation for correcting beam pattern effect, show that they are within the manufacturer's specifications (12 dB, on two-way, near the edge of the sound beam, with variation of ± 1 dB on one-way, an expected variation of ± 2 dB on two-way).

Fish Target Strength

The recorded data were processed to extract and calculate single fish Target Strength detected by echo-sounder. There were 141 independent single fish echoes extracted. The range of fish Target Strength is between -55.6 dB to -48.6 dB. The mean Target Strength is -53.8 dB, with the standard deviation of 1.4 dB. Figure 7 shows the distribution of single fish Target Strength detected by echo-sounder.

Fish samples taken from local fishermen operating purse-seine net in the area consisted of single species, mainly anchovy (*Engraulis japonicus*). Samples of 100 fishes were randomly taken and measured. The body length of fish sample is in the range of 5.1 cm to 10.3 cm. The mean body length is 7.3 cm with the standard deviation of 0.8 cm. Figure 8 and 9 show the body length and weight distribution of fish samples respectively.

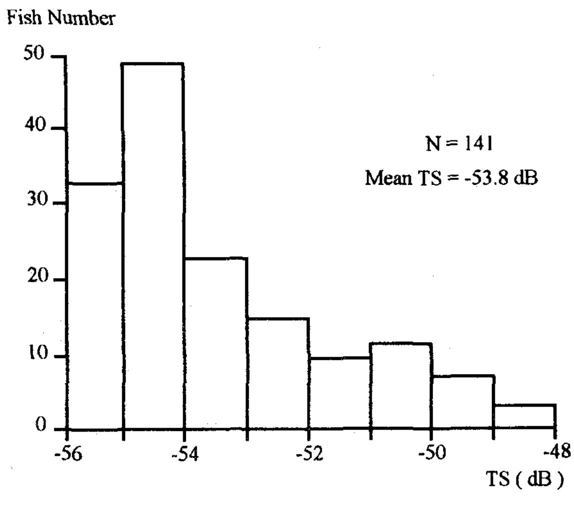


Figure 7 Fish Target Strength distribution detected by the Split Beam echo-sounder.

Gambar 7 Sebaran besar ukuran ikan pada echo-sounder *Split Beam*.

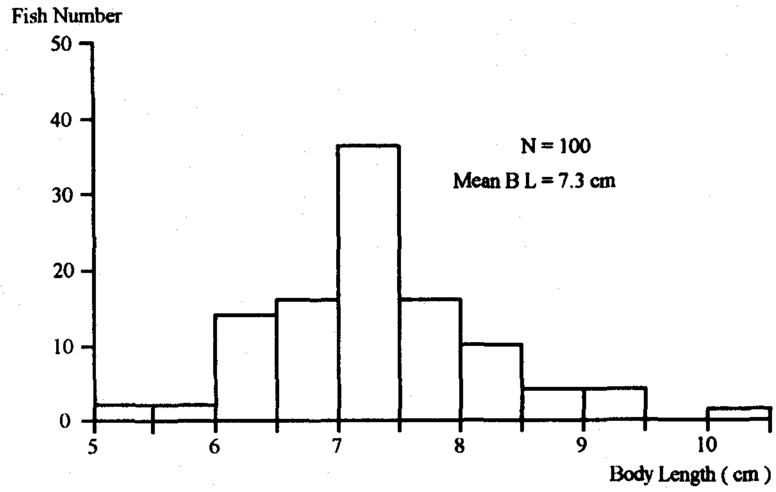


Figure 8 **Body length distribution of fish samples.**
Gambar 8 **Sebaran ukuran panjang ikan.**

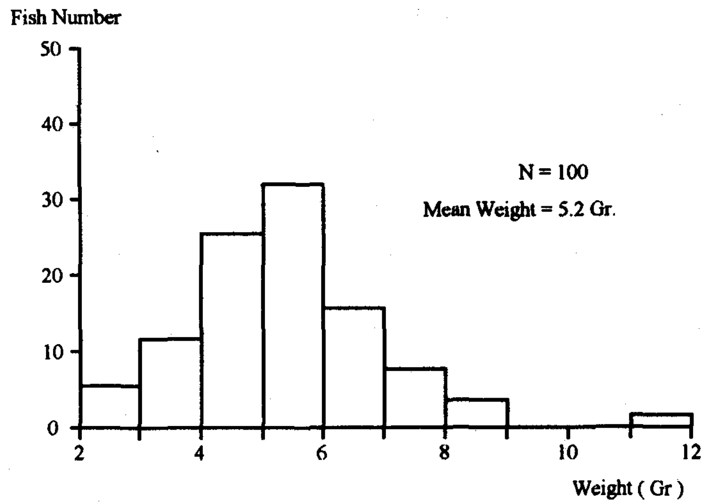


Figure 9 **Weight distribution of fish samples.**
Gambar 9 **Sebaran bobot ikan.**

DISCUSSION

The presented material shows that the acoustic data of a sphere and free swimming fish can be collected through the parallel output data of Split Beam echo-sounder. Using this facility, the beam pattern of the transducer can be determined. The equation, representing the beam pattern, can be used to remove the effect of beam pattern from returned fish echoes and then to obtain the fish Target Strength.

According to the report by the Japan Research Institute of Fisheries and Engineering[1], the relation between the Target Strength and the body length L of anchovy is : $TS = 20 \log L - 31.2$ (measurements were done in the tank test with an anaesthetized anchovy). Deducted from this equation, the fishes detected by echo-sounder, during the experiment in the Tateyama bay, could be anchovies.

[1]Japan National Research Institute of Fisheries and Engineering, 1984. List of measurement of TS, domestic and overseas (in Japanese).

ACKNOWLEDGEMENTS

The Captain and all the crew of the research and training vessel Seiyo Maru are gratefully thanked for their assistance during the study. Many thanks to Mr. K. Ito and the fishermen of the Tateyama Bay for providing fish samples.

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Foote K.G., Kristensen F.H. and Solli H., 1984. Trial of a new Split Beam echo-sounder. International council for the exploration of the sea.

DISCUSSION

(Chairman Dr. MARCHAL)

Mr. MUNANDAR

Q : - What do you think about multiple echoes ?

A : - The transducer can get multiple targets; we did only single fish Target Strength measurements. I tried to collect the raw data and postprocessed them one by one to obtain their TS. You can make programs by your own. There are also special programs that can be used to discriminate multiple echoes.

Dr. GERLOTTO comments : "I would like to recall this : TS problem is a real problem for all the whole international community. The International Council for the Exploitation of the Seas, ICES, has spent a lot of work and time for this problem; many study groups have been developed to work on it. It will be published a cooperative report this year on TS problems, methods and biases. I suggest to everybody to write to ICES, in Denmark and order this document. It will be helpful and valuable for those who work on TS."

Q : - I have 3 questions. First : what was the frequency of your echo-sounder ? Secondly : why did you choose such a large pulse length for your study ? The third one : you have shown bimodal TS distribution and unimodal distribution of fish. Maybe, the mean TS value is not the most appropriate. Mean value signifies that you mixed two groups. Either these 2 groups exist in the sea and the fishermen just caught one, or the small TS values are some artifact and in most case, the mean value may bias the relation ?

A : - The frequency was 70 kHz. Our echo-sounder only has two pulse settings : 0.5 ms and 1 ms. I have made many experiments. The 0.5 ms pulse is not long enough to reach the peak mean because the number of samples of the signal, after digitalization, is only 3. Of course, when you use 1 ms, the resolution is longer. It means that 2 fishes have to be separated at least at 75 cm of distance to be discriminated. It is a compromise that you have to deal with. Moreover, the chosen pulse length and thus the raw data had to match with our program. These data are *in situ* data. I have no samples from fishermen. Japanese searchers reported the relation between the length and the TS of the *Engraulis japonicus* and I applied these values on my results.

ECHO-INTEGRATION APPLIED TO FISHERY ASSESSMENTS : A STUDY ON SCATTERING AND ABUNDANCE OF EXPLOITED STOCKS[1]

J. MASSÉ

ABSTRACT

This paper summarizes the combination of technical procedures used for acoustic assessments, and the results of acoustic surveys that pertain to the dynamics of the stock of anchovy (*Engraulis encrasicolus*), in the Bay of Biscay, between 1990 and 1994. A short synthesis about the method is done, then some results are discussed. Information is presented on the distribution and abundance of anchovy and occurring species, and on the movement patterns detected within the pelagic fish community, in relation to the environmental conditions. A comparative analysis of the vertical distribution of echo traces revealed some species-specific preferences. Beyond the stock-assessment possibilities, these last few years' experiments showed that acoustic survey methods can provide considerable knowledge used for ecological research.
KEYWORDS : acoustic, anchovy, Biscay, schooling, pelagic, behaviour.

ABSTRAK

Tulisan ini mengulas tentang prosedur teknik yang digunakan dalam penilaian akustik, dan hasil-hasil penelitian akustik yang berhubungan dengan kedinamisan stok ikan teri (Engraulis encrasicolus), di Teluk Biscay antara tahun 1990 dan 1994. Sebuah sintesa singkat tentang metode ini telah selesai dikerjakan. Kemudian, beberapa hasilnya telah dibahas. Informasi mengenai penyebaran dan kelimpahan ikan teri dan jenis-jenis ikan lain yang berada di sekitarnya, dan mengenai pola pergerakan yang ditemukan di dalam komunitas ikan pelagis dalam hubungannya dengan kondisi lingkungan, telah dipaparkan. Sebuah analisis perbandingan mengenai penyebaran vertikal pelacakan gema menampakkan adanya beberapa jenis ikan khusus. Di luar kemungkinan perkiraan stok, penelitian-penelitian beberapa tahun terakhir menunjukkan bahwa metode penelitian akustik dapat memberikan pengetahuan yang memadai untuk digunakan dalam penelitian ekologi.
KATA KUNCI : akustik, ikan teri, Biscay, kawanan ikan, ikan pelagis, tingkah laku.

[1] Reprint from Oceanis volume 22,1

Comprehensive management for a resource, first and foremost, requires a good knowledge of availability, abundance, repartition and turnover.

Halieutic resources cast problems as for their mobility, the area of repartition and their turnover capacity varying within time.

Several direct or indirect methods used to assess those resources suit more or less to some species, considering their habitat and behaviour.

In the case of pelagic species, characterized by an important vertical component for their dispatching, heavy migrations and huge abundance fluctuation, acoustics has been the most developed tool ever since the 70s.

Qualitative and quantitative analyses of reflected echoes on targets, spread along a water column, are frequently called "echo-integration". This method shows several advantages such as a good ratio between time and prospected area, as well as a short gap from prospecting to quantitative processed results on.

Acknowledgement on the limits of this method intervened quite early and many methodological studies allowed to rapidly focus on bias, which could affect abundance estimates.

Thus, results now displayed are considered as relative abundance index rather than fully fledged estimates. As it aimed at following a population evolution during several years, that kind of index is relevant and thus frequently used by teams studying fish stocks of commercial interest.

Another asset of the method lies in the fact that direct observation of concentration allows to take into account every species present, as from the abundance point of view, and scattering and behaviour as well. Along with sample fishing and environmental data, these of acoustics turn out to enthral ecological knowledge.

METHODS

First used to investigate the seafloor, marine acoustics has been soon used by fishermen to locate fish schools. Technical improvements, as well as data processing on, have allowed, from the 70s (Johannesson and Losse, 1977) to consider using data for abundance estimates.

Once corrected by losses in water - as geometric dispersion and molecular absorption - echo intensity, reflected by a target, becomes directly proportional to its density. No wonder that detection has been applied to fish tonnage evaluation from acoustical energy on.

This chapter does not aim at explaining acoustics theories nor echo-integration ones, but it handles with reminding the principles of the method. Several former articles have been issued on that topic, and newly released syntheses (Mac Lennan and Simmonds, 1992; Diner and Marchand, 1995) have more about it.

Basics

The acoustical energy, reflected by a target, is function of its nature. In the case of fish, it varies according to both the species and the size. This feature is commonly called "TS" for Target Strength, or reflection index. It is generally assumed that 2 fishes belonging to the same species, same size, supposedly oriented in the same way within an acoustic beam, do reflect the same amount of energy, for the same emitted acoustical intensity. Still, 2 fishes of same size, but of different species, do not reflect the same amount of energy since their anatomy and especially their swimbladder (Foote, 1980 a) stand for a particularly effective reflector.

Given that, in situ and in vitro experiments allowed to set TS curves, according to fish size, for several species. Even if those measurements are now questioned, settled relations, for more than 15 years for some of them, (Foote, 1979; Vorobyov and Ivanov, 1981; Naken and Olsen, 1997) finely account for specific differences and reflection feature evolution according to the size. Though it is not possible to measure a biomass of fish in a given volume without catching them, it is possible to measure up energies reflected by these targets, then to translate them into biomass.

It demands to carry out acoustic survey on the study area, in order to quantify observed echoes and to identify targets. This is done through scientific trips, using specially equipped boats.

Surveys

Prior to any survey, some knowledge is essential, such as : approximated area of distribution for the different species generally present on the zone, as well as some notions about targeted species (such as day/night migrations for instance).

The goal being to assess the abundance of one population, it is first necessary to determine a radial net adapted to the topography as well as to the fish concentration mode on the spot. Different strategies of sampling can as well be used, such as parallel radials (Fig. 1) or zigzag pattern for example.

Along those radials, any detected echo, within the dynamic range of the echo-sounder, is taken into account, both in number and energy.

Pelagic trawlings are carried out in the areas where detections have been made in order to determine the specific composition and to characterize each species from a biological point of view.

Acoustical system is eventually calibrated with a standard target whose TS is well known, in order to define the transmission and reception capacities of the equipment. This echo-integration constant, adapted to the TS for the species studied, allows to convert acoustical energy values into biomass.

Results and exploitation

By computing data acquired on radial prospecting and identification fishing, it is possible, as a first step, to map and measure up the concentration areas of the targeted species (in square miles). Once acoustical data are cleaned up, having swept out undesirable echoes (such as parasitical noises or plankton, and when targeted species are fish, some fortuitous echoes), a mean density value by surface unit is processed. This process is facilitated, given that measured energies have been already sorted by water layers and cleaned up by thresholding most of the time. More in-depth analyses allow then to study vertical fish distribution for instance, and permit to characterize aggregating systems, or to match these values along with other parameters such as environmental features, for example.

Technological developments

Scientific acoustical systems have been changing for the last 10 years because of data numeric format and computer-linked analysis. Hence, new technologies were released, either Dual or Split Beam, that, being used with proper software, allow data storage as well as processing possibilities.

One of those systems is IFREMER's INES/MOVIES (Diner *et al.*, 1989) which digitizes the electric signals from the echo-sounder, stores and analyzes the data. It records both the whole acoustical and navigation data. This new device provides trailblazing possibilities in treatment, once used with upgraded methods of analysis. As for itself, it comes up to the software MOVIESB (Weill *et al.*, 1993) which now allows to integrate school by school echoes, instead of integrating water columns, as previous systems do. This method of analysis, alike image analysis, not only gives density values, but also several parameters as for aggregation shape and scattering in the water strata that characterize spatial occupation by living bodies. It hence allows an original approach of classification of schools and aggregating systems of pelagic species, easier to locate in their environmental complex.

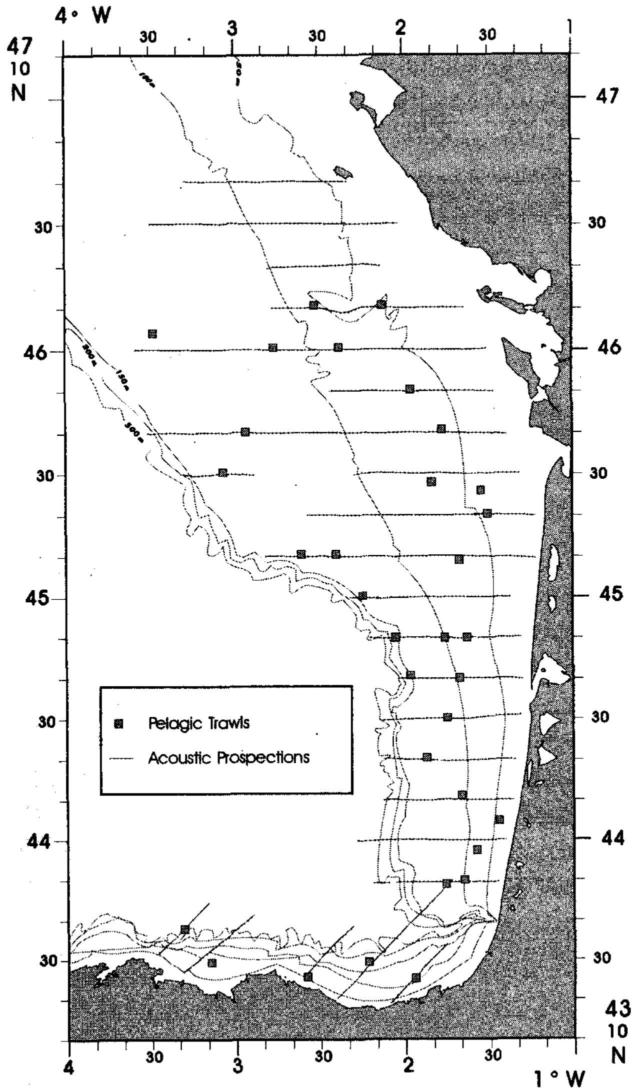

Figure 1 Location of acoustic transects and midwater hauls during the 1994 acoustic survey. The other surveys of this study followed a similar sampling strategy.

Gambar 1 Lokasi garis temu akustik dan penangkapan di perairan tengah yang dilakukan selama pengamatan akustik pada tahun 1994. Pengamatan-pengamatan lain yang dianggap termasuk dalam penyelidikan ini mengikuti strategi sampling yang sama.

THE RESULTS

Studies realized through this new software (Scalabrin, 1991; Massé and Rouxel, 1991; Scalabrin and Massé, 1993) allow to characterize some types of detection and to study their variability. For present species, the schools' shapes seem to remain the same from one year to another, according to the bathymetry, whereas important variations in size are noticed from year to year. This phenomenon probably comes from changing environmental conditions, expressing a modification in gregarious behaviour that could interfere in the potential success of a species recruitment.

The results, displayed here, stem from 4 acoustical surveys carried out in the Bay of Biscay, between 1990 and 1994. Their first aim was to set a yearly abundance index for anchovies (*Engraulis encrasicolus*) at the beginning of the spawning period, then to follow its evolution to provide data helping to stock management. It appeared that following abundance was not enough and that understanding mechanism modifying abundance variations was of utmost importance. This made the study aiming to a deeper analysis of relations between environment physics and adults repartition.

Abundance

It has been mostly expected to assess commercial fish stocks and to follow their evolution. These data can then support models of population dynamics, in order to set reliable assessments for fishery management.

Reliability

A first step was to check the available abundance assessment tools. Spanish and French scientists gathered their results within the frame of the Fisheries and Aquaculture Research European program (FAR) that ended at the beginning of 1994. Three types of indexes were then compared :

- abundance index provided by echo-integration (IFREMER surveys),
- biomass sires evaluation, based on spawning estimation and fecundity studies (surveys of Spanish Basque Institute : AZTI),
- CPUE (Catch Per Unit Effort) index provided by Spanish fisheries.

These several indexes (Fig. 2), expressed in number of one-year-old anchovies (accounting for 70 to 90% of the biomass depending on the year), show very similar evolutions, thus supporting the method reliability.

This has been widely used for 15 years to assess abundance of some commercial pelagic species; advantages and drawbacks can be established as follow.

Advantages

- It is possible to carry out an acoustical prospecting within a short gap, then, most of all, to come out results quickly, *i.e.,* the following week.
- It allows to observe simultaneously any living being in a water layer, that means especially to distinguish between different species in a given volume.
- Observing living being and other parameters can easily be coupled up, in a same time or space scale, such as environmental data for example.
- It permits to link distribution and abundance of a species with its behaviour, thanks to the description of aggregating systems, for instance.

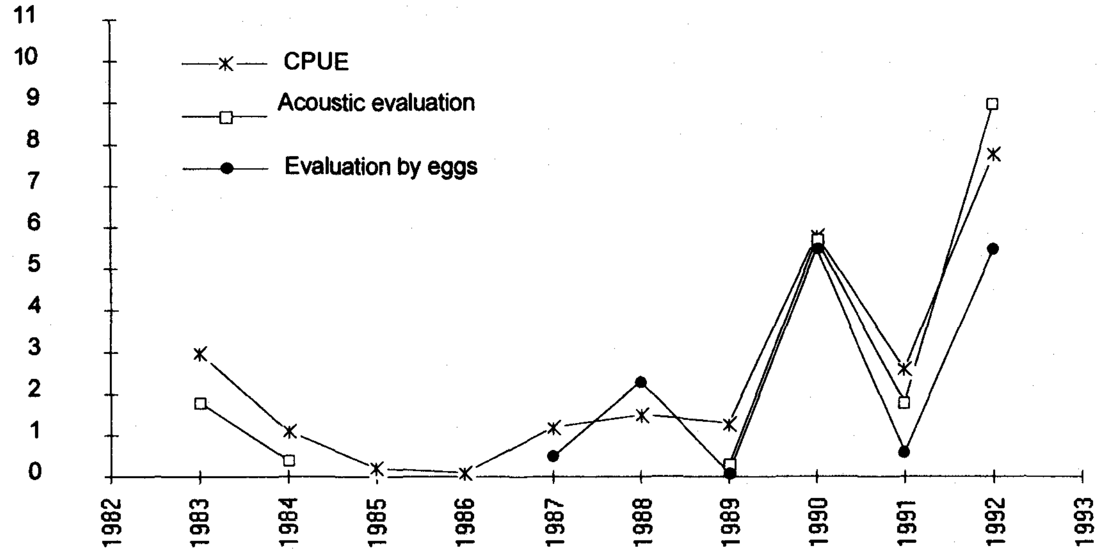

Figure 2 **Abundance indices of one year old anchovy obtained from acoustic surveys, egg surveys or Catch Per Unit Effort (CPUE), in the Bay of Biscay since 1983.**

Gambar 2 **Indeks kelimpahan ikan teri berumur satu tahun yang diperoleh dari penelitian-penelitian akustik, penelitian telur-telur atau usaha penangkapan per unit di Teluk Biscay sejak tahun 1983.**

Drawbacks

- Specific behaviours, such as fleeing in front of the ship, or the trawl, are difficult to figure out (Diner and Massé, 1987; Misund and Aglen, 1992).
- One to five metres thick layers just under the surface, or from the seafloor, are unexploitable. Those so-called "blind zones" depend on the system efficiency and the condition of use (distance from transducer to surface, width of the beam, pulse duration ...).
- Identifying detections is difficult, whereas it is essential, because TS can highly vary from one species to another.

Space organization

In the field of halieutic research, this method used to be developed only for assessing biomass. Ever since, it has been providing other data such as space population disposal, both geographically and vertically; that turned out to be useful for better comprehension of ecosystems. Results and figures displayed hereafter have already been published in two recent articles (Massé, 1996; Massé *et al.,* 1996).

Horizontal distribution

Data, collected from formerly described surveys for anchovy's stock assessment, allow to focus on the species repartition, then to compare it to environmental parameters.

Areas of anchovy presence were discriminated, through OEDIPE software, from acoustical data and fishing results from trawlings. Along with these data, were recorded temperature and surface salinity (but for the 1990 survey, lacking salinity data). Vertical temperatures and salinity profiles were acquired on stations set up along radials. Isotherms were plotted through SURFER software. Figure 3 shows anchovy concentration areas observed during each survey, associated with thermic and saline conditions. It is first noticed that this distribution varies from year to year, both in extension and geographical position.

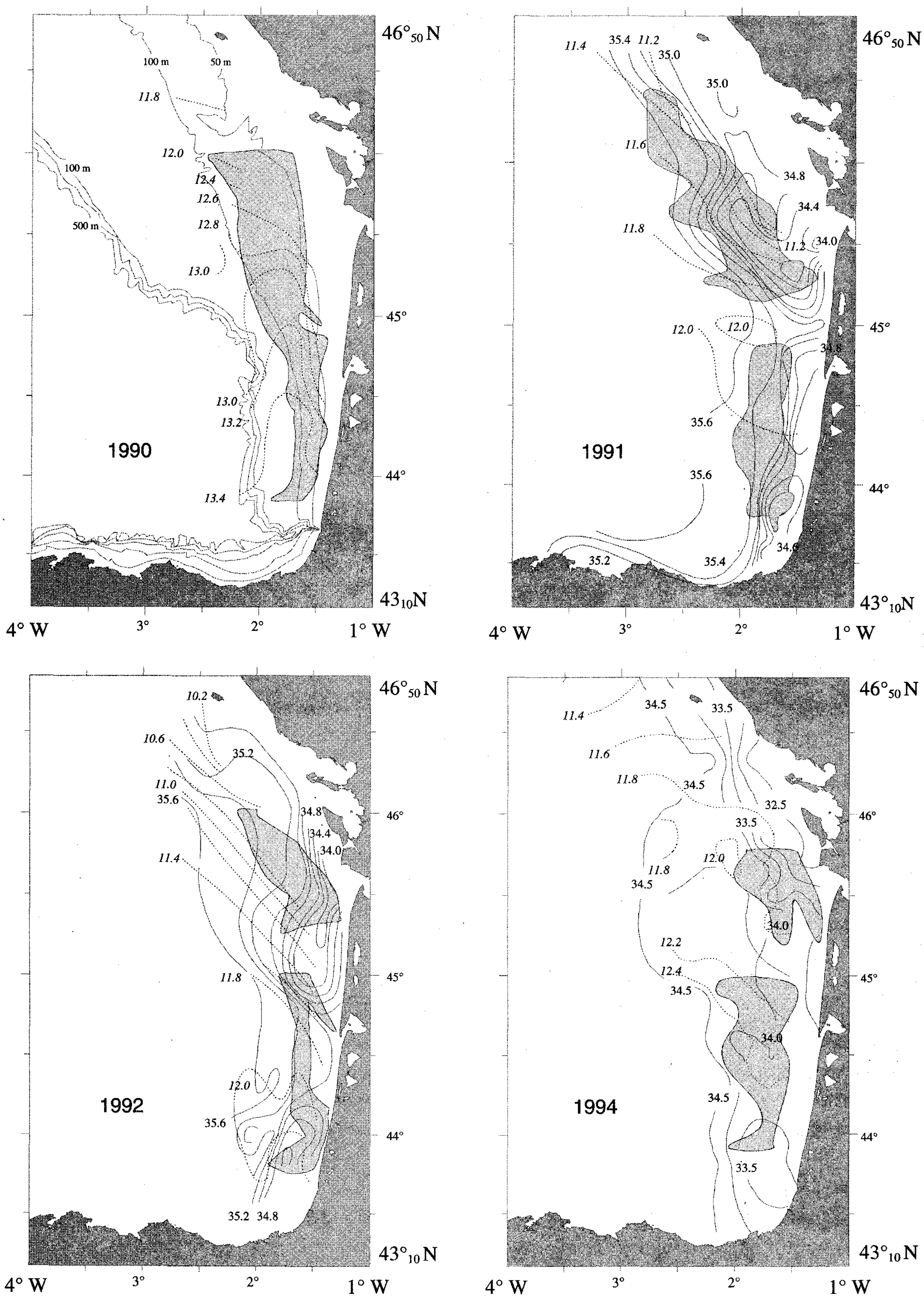

Figure 3 **Horizontal distribution of adult anchovy, salinity and temperature.**
Gambar 3 **Penyebaran horisontal ikan teri dewasa, salinitas dan suhu.**

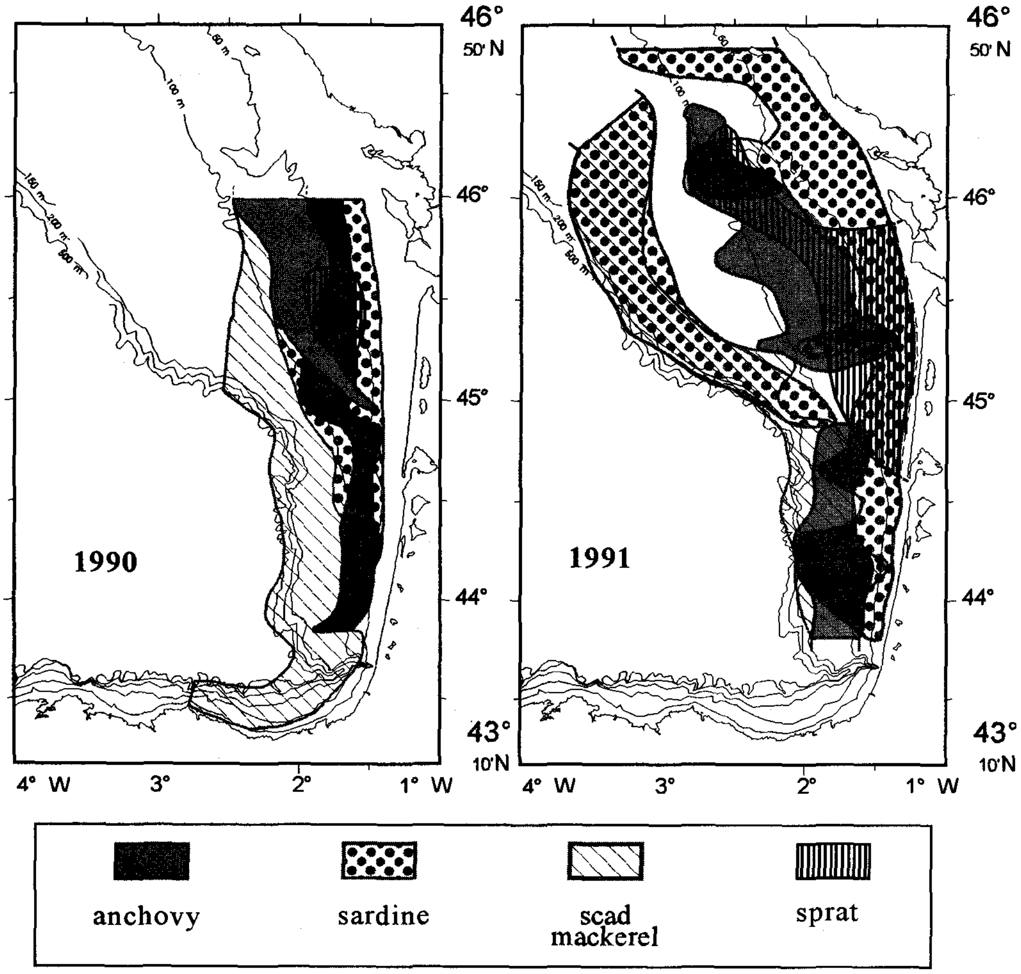

Figure 4a **Horizontal distribution of pelagic species observed in April 1990 and 1991 (Massé, 1996).**

Gambar 4a **Penyebaran horisontal jenis-jenis ikan pelagis pada bulan April 1990 dan 1991 (Massé, 1996).**

In 1994, for example, contrarily to the other years, anchovies did not come upper 45° 30 N. In 1991 and 1994, the area of extension looks larger especially in the South of the continental platform. Finally, a discontinuity often show up around 45° North, approximately corresponding to a thermic gradient owing to the fresh and cold water pouring from the Gironde Estuary.

If anchovies appear along with other species in the same area, distribution and most of all cohabitation area vary from one year to another. Four species were to be parted on Figure 4, from detection and catching from pelagic trawlings :

- anchovies,
- sardines,
- sprats,
- scads (coupled with mackerels for a small amount in this study).

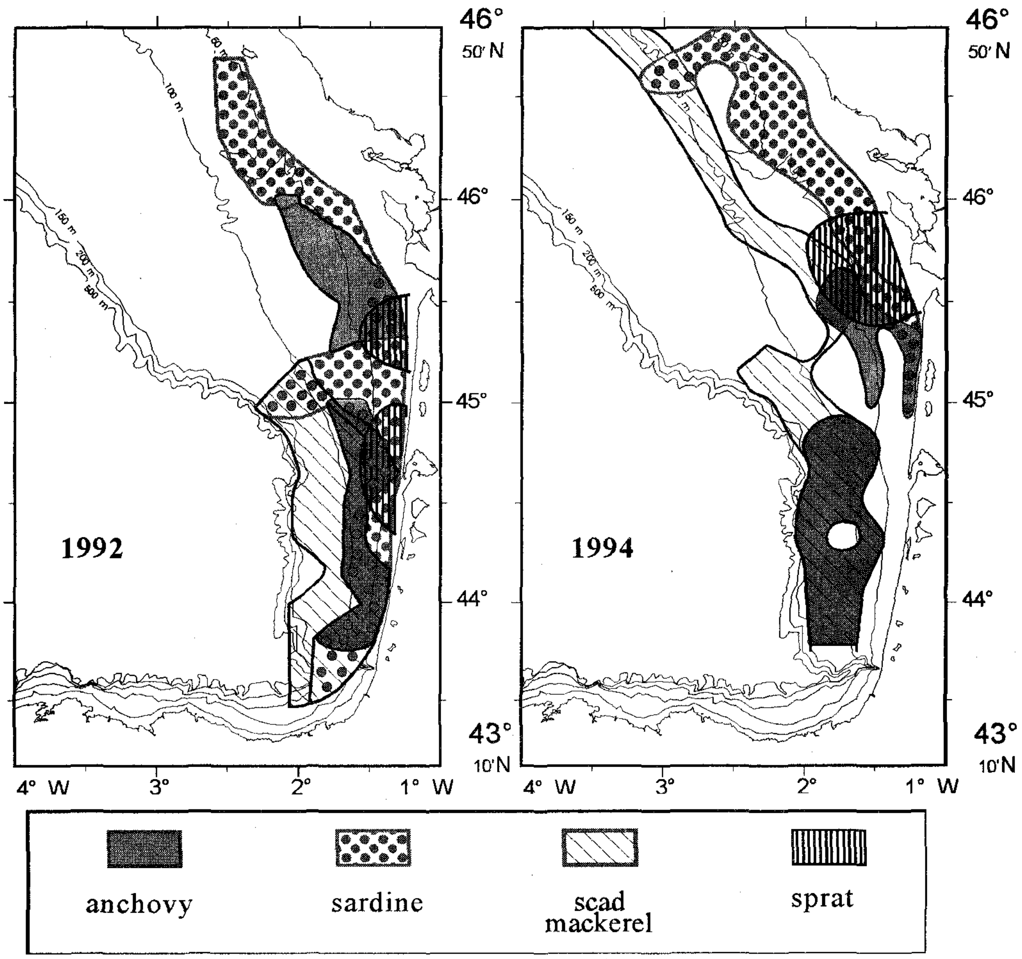

Figure 4b **Horizontal distribution of pelagic species as observed in April 1992 and June 1994 (Massé, 1996).**

Gambar 4b **Penyebaran horisontal jenis-jenis ikan pelagis pada bulan April 1992 serta bulan Juni 1994 (Massé, 1996).**

Sardines are mostly met along the coast, their expansion to the South varying, and not found in the South of the Gironde, in 1994. They also appear along a continental platform breach in 1991, but there is no inter-annual comparison possible, since this area has not been surveyed the other years.

Mackerels and most of all scads rather far from the shore, are always present, and their cohabitation with anchovies is more or less important. At last, sprats essentially concentrate off the Gironde and Arcachon, their distribution areas vary from year to year, and they indifferently live along with anchovies, sardines and scads. It is interesting to notice that areas, where anchovies inhabit lonely, are uncommon, and that the only pure anchovy concentration areas, observed through years, have been located off the Gironde.

Vertical distribution

Figure 5 shows how those species share vertical layers. One of the radials prospected was chosen in the area where Gironde estuary stream is present. Thermic vertical profiles were established from vertical probes made down-right on it, and aggregation pictures were taken from echograms provided by MOVIES, the same day.

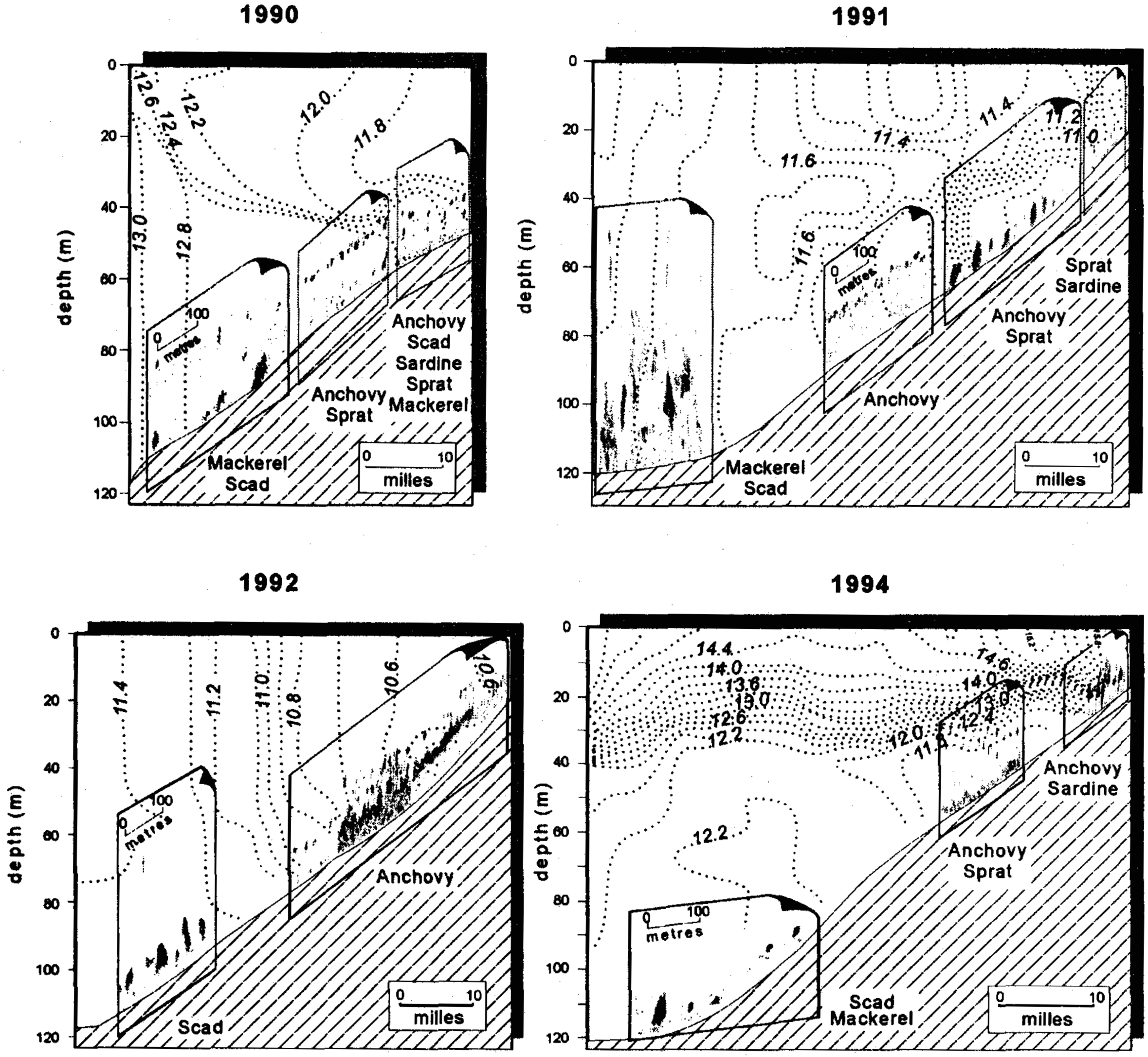

Figure 5 **Vertical distribution of adult fish, in front of the Gironde in April 1990, 1991, 1992 and June 1994 (Massé, 1996).**

Gambar 5 **Penyebaran vertikal ikan dewasa, di depan Gironde pada bulan April 1990, 1991, 1992 serta bulan Juni 1994 (Massé, 1996).**

This vertical distribution of adult fish is based on acoustic surveys, pelagic hauls, and temperatures as observed during surveys in front of the Gironde in April 1990, 1991, 1992 and June 1994. The transect was perpendicular to the isobaths. The aggregation pattern observed in 1992 was very unusual and coincided with an unusual homogeneous vertical temperature profile.

First, a quite classical bathymetric distribution can be noticed (Scalabrin and Massé, 1993): horse-mackerels and most of all scads at 90 to 120 m deep, the clupeids, as anchovies associated with sprats or not, down to 40-50 m deep and finally anchovies, sardines, sprats near the shore.

Scad detections occur off the coast, as big rough bulks, close to the seafloor, as high as 10 to 40 m.

Anchovies rather appear as pelagic shoals aligned 15/20 m above the floor. This feature, in the Bay of Biscay, has been noticed along the years, as well by scientists as by fishermen. Exceptionally in 1992, this species turned out to constitute dense layers, stuck to the seafloor. An unusual vertical homothermy in the area, at this time of year, could explain it without having been verified. At last, clupeid coastal associations come to different shapes, but often composed by distinct schools.

Multispecific behaviour

According to the previous statements, it was interesting to analyze in details the way species do bear cohabitation with others, either closely related (e.g., for clupeids) or not (as anchovies and scads). These species can interact by competition or even predation.

Taking into account the results of trawlings, 4 types of system have been considered in the surveyed area for the 1994, according to the present species :

- anchovies only,
- scads only,
- anchovies associated with scads,
- anchovies associated with Sprats.

About 5,500 schools, observed on those areas, were scanned through MOVIESB (Massé *et al.*, 1996). Each school was characterized through its size, its shape, the energy reflected, and the depth in the water layer. From this primary work, we observe almost constant characteristics of energy and shape within the same community. Few pictures are displayed on Figure 6.

Anchovies show small shoals, quite dense, with a vertical section, within 20 to 50 m^2, for a density index around 25 (that index varies from 5 to 35 in this study), perfectly lining 15 m above the seafloor. As for scads, it appears as large, rough and quite loose detections, with a vertical section from 20 to 150 m^2, for a density index of 15. These are generally detectable from the floor up to 15 m or more. If anchovy school's features seem steady taken alone, it changes with sprats or scads. In the first case, schools are impossible to separate and appear vertically stretched, more dense (index : 35) and roughly scattered in a water layer from the seafloor to 30 m above. As it flocks together with scads, each species can be perfectly differentiated. Scad schools do not vary in shape. They are always stuck to the floor, the vertical section shape and density being similar to the latest description. Anchovy's schools, in size and shape are similar, but they do reflect less energy (density index : 12) and line on 20/25 m above the floor, that is 10 m higher than when alone.

It would tend to prove that cohabitation between anchovies and sprats is quite easy, even in multispecific schools, as it often appears in tropical areas for similarly sized individuals (Fréon, 1984). Still, cohabitation between scads and anchovies looks harder and an obvious trend for anchovies to swim up in the water layer could be associated to stress reaction, because of alleged predators; moves and tilting of fish in the acoustic beam modify its reflection index (Foote, 1980b).

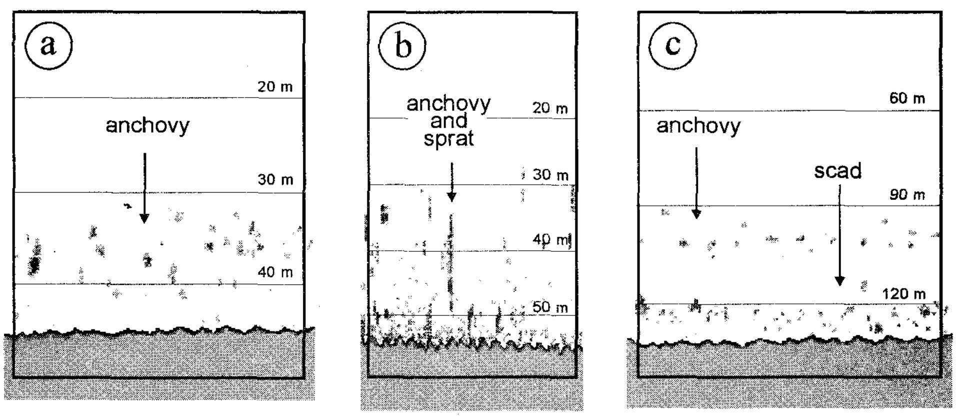

Figure 6 **Typical echo-traces observed in areas where anchovy was alone (a) or shares space with sprat (b) or horse-mackerel (c) (Massé, 1996).**

Gambar 6 **Kekhasan pelacakan gema yang diteliti di daerah di mana hanya ada ikan teri (a) atau ikan teri yang berbagi tempat dengan sejenis tembang (b) atau sejenis ikan-ikan skombrid (c) (Massé, 1996).**

CONCLUSION

Acoustics use for marine research has been improving a lot over the past 20 years. Along with technological progress, users have been coming to apprehend the limitation of the echo integration methods, hence sharpening sampling strategies and statistical processing (Marchal and Petitgas, 1994; Massé and Retière, 1995), and bettering the ratio cost/efficiency. If evaluation can sometimes be questioned in terms of absolute biomass assessment, indexes (at least relative ones) of abundance have been now commonly used in order to follow commercial fish stocks, either directly or in complement of other methods.

In order to meet the first goal that was acoustical biomass assessment, users reached the precision limits of the system, thus stepping to other fields such as ethology. Indeed, school behaviour (Gerlotto and Marchal, 1987; Soria, 1994) or individual behaviour (Mac Lennan and Menz, 1996) can directly affect the detection features during a survey.

Technology, as well as developments, thus focused on fine studying individual target reflection, or on characterizing aggregates. It leads to such release as MOVIESB software, or more sophisticated systems such as Dual Beam system, Broad Bandwidth or multi-beam system. These new tools should always bring finer measures, and most of all a better characterization of targets, in 2 or 3 dimensions.

In the same time, marine fishery scientists, in charge for studying population dynamics and resource management, established that, for some of those resources, yearly knowing the biomass was not enough to set a reliable assessment on the state of the resource to come. It is all the stake for so-called "unstable" resources, such as small pelagic species as anchovies, for which recruitment fluctuations are often blunt and not understood. The research thus steadily focused on studying determinism for these fluctuations, both in distribution and abundance, through a more systematical pattern. Following the stocks is by now often matched with studying environmental parameters. The way fish share space, sometimes temporarily, even seems to reflect the state of each populating component by now.

Stocks' studies by acoustics and research in population dynamics thus seem to move in the same way, and acoustical tools upgrade more and more adapted to marine fishery scientist needs. Biologists even come to consider observed populations in their globality as "acoustical population" (Gerlotto and Marchal, 1997), taking into account all the species present in a given volume and so granting as much of importance to fish behaviour and fish environment as to abundance assessment. May be too much time was spent trying to count fish as precisely as possible ... without considering how they behave individually and in their community. Keeping in mind how much could be killed, it was neglected to consider how they do live.

But what about fish for their own ?

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DISCUSSION

(Chairman Dr. FATUCHRI)

Dr. ILAHUDE

Q : - Your surveys last a long time. At what point do you start to make only Acoustics ?

A : - We make Acoustics and sampling all along the survey. Fish schools move very fast and we have a statistical strategy. We do the transects and never stop. Each time we meet a structure, we trawl. We make Acoustics during 10 hours and around two trawling operations a day. A cruise lasts 12 or 13 days.

Q : - Do you still use these 35 parameters to distinguish the different schools when you meet mixed species ?

A : - We cannot define them. In a cluster, you can do it after the survey. Usually, we make a haul in different layers and we combine the description with the species caught during this haul. In this way, the catch can be corrected.

Mr. RUSTAM

Q : - You told us than the fishing effort was not a problem for the anchovy fishery. Do you mean that the environment factors are the main limiting parameters in that area ? Is the biology of the fish affected by the environment ?

A : - If the fishing effort increases, the rate of exploitation will increase. However, it is not the predominant factor. The objectives of the new program will not be only the monitoring of the biomass but also a better understanding of the dynamics of the pelagic system.

Q : - What about the pollution ?

A : - During the two last surveys, we analyzed the primary and the secondary productions. The question is : what are the predominant factors ?

Q : - What is your personal conclusion about these surveys ?

A : - We still have to go further in technical research. I believe that new technology as wide band echo-sounders or multi-band lateral echo-sounders which give three-dimension view of fish schools. For managers, it is less important to have an instant biomass than an evolution of this biomass. Therefore, we always use the same TS values to follow that evolution.

GREGARIOUSNESS AND SCHOOL BEHAVIOUR OF PELAGIC FISH : IMPACT OF THE ACOUSTICS EVALUATION AND FISHERIES

F. GERLOTTO

ABSTRACT

Pelagic fish (Clupeids, Carangids, Engraulids, Scombroids, etc.) are normally forming dense schools, gathering over tens of thousands of individuals. This paper defines the concept of fish schools for fishery acoustics, and describes briefly their main dynamic mechanisms. The kind of spatial distribution, due to this behaviour, makes necessary the design of appropriate sampling methodologies. This paper also describes the main acoustic tools applied on fisheries studies, and their characteristics. The effect of the heterogeneity in the spatial distribution of fish density is discussed. The impact of gregariousness on the validity of acoustic data is described, as well as the main behavioural features : horizontal and vertical school avoidance, acoustic shadowing, diving and dial cycles are factors to be taken into account in the acoustic methodology. Under some favourable conditions these behavioural characteristics may help to improve the knowledge of a stock, and sometimes to identify the species.

KEYWORDS : Acoustics, methodology, school, behaviour, biomass, deviation.

ABSTRAK

Jenis-jenis ikan pelagis (Clupeidae, Carangidae, Engraulidae, Scombridae dan lainnya) ummumnya membentuk kelompok yang padat yang terdiri atas ribuan individual. Tulisan ini mendefinisikan pengertian dan penjelasan singkat tentang kelompok ikan pada akustik perikanan serta dinamikanya. Sifat distribusi spasial yang berhubungan dengan tingkah lakunya menyebabkan perlunya rancangan yang sesuai pada metodologi pengambilan contoh pada saat penelitian. Tulisan ini juga menjelaskan aplikasi metoda akustik pada penelitian perikanan serta karakteristiknya. Demikian pula pengaruh heterogenitas pada distribusi spasial kepadatan ikan, peranan sifat pengelompokan ikan, pola tingkah laku, penghindaran mendatar dan tegak, "acoustic shadowing" serta ruaya harian yang merupakan faktor-faktor yang harus diperhitungkan terhadap data pada aplikasi metoda akustik. Pada keadaan tertentu pola tingkah laku tersebut dapat membantu perkembangan pengetahuan suatu stok bahkan pengenalan jenis ikannya.

KATA KUNCI : Akustik, metodologi, kelompok ikan, tingkah laku, biomas, penyimpangan.

One of the most remarkable characteristics of fish behaviour is their gregariousness. The great majority of species is permanently or occasionally (during one life episode or only seasonal) grouped in schools. This behaviour turns out to be of great importance for exploitation: about 70 million tons of the annually ocean fish product (FAO, 1995), almost 80 %, come from gregarious species. Fishing adapted to this behaviour turn into an advantage : should it be that oceans had to be filtered through to extract fish, exploitation costs would turn greatly higher than they actually do, thanks to devices adapted to this behaviour such as trawls and ring nets. Theses are the most productive fishery devices ever invented, and particularly since these acoustics tools can locate schools in water. They have been designed keeping in mind gregarious behaviour.

Meanwhile, this gregarious behaviour shows several spatial and temporal features, that have a strong impact on acoustics assessments : dispersal, concentrations, dynamic behaviour, etc. This work describes the spatial characteristics and their impact.

WHAT IS A SCHOOL?

Definitions

The first scientific studies dealing with schools had been carried out upon an average of small-scale groups, only some individual or at most 10 subjects, inside several aquariums or ponds. Despite their limits, those works allowed to establish basic rules concerning gregarious behaviour. Be just named the pioneer works of Radakov (1973), which is still of authority. Subsequently, scientists tried to verify if this mechanism could be observed within Nature.

This opening to real life can be found in Bardach *et al.* (1980), for example, or in Pitcher (1986). But these in situ observations turned out to be difficult, and it is only since the 90's that studies about schools have been performant to really examine schools in their own natural environment.

To sum up a definition given by Soria and Dagorn (1992), "a school of fish can be described as a provisional group of individuals, generally from the same species, the same size and within the same biological cycle, united by a mutual attraction, and showing different degrees of coordination of their swim ability within a centered group. They maintain constant contact, mostly visual, but by acoustics and olfactory means as well. These individuals can, at any time, come to an organized action that uses the same biological skills for any member of the group. We observe a synchronisation of individual movement inside the school." It also needs to be distinguished right away between school and aggregation : "aggregations are collections of animals of one or several species. An aggregation is a result of individual animal's attraction against a precise characteristics of the environment. We talk about aggregation when social attraction does not exist (Eibl-Eibesfeldt, 1984)." (Soria and Dagorn, 1992).

Organization and functioning of a school

From visual observations and underwater photos, it had been believed for quite a while that schools were completely regular structures where fish occupy situations strictly linked to their neighbourhood. At such a point that some works show a "cristalline" structure of schools, where every fish occupy the place of an atom inside a rhomboedrique crystal lattice (Breder,1976). This structure was found on numerous observations, mainly carried out in isolated environment, even aquariums, that actually showed a tendency of a fish to place itself at an "optimal" distance from its neighbour. And the determinism of this position was based on individuals' reaction to sound and pressure waves emitted by fellow creatures.

Subsequently some writers, observing schools in their own natural environment, particularly with acoustics (Cushing, 1977; Gerlotto and Fréon, 1988; Misund, 1993) or visually, have refused the hypotheses that, in their general structure, schools showed a very strong heterogeneity, forming large empty vacuoles. These observations were in accordance with more general observations in acoustics upon schools, with average densities from the majority of ocean species, which seldom are higher than 3 individuals per meter cubic (Simmonds *et al.*, 1992), which was obviously contradictory to the theory on the school homogeneity (Fig.1).

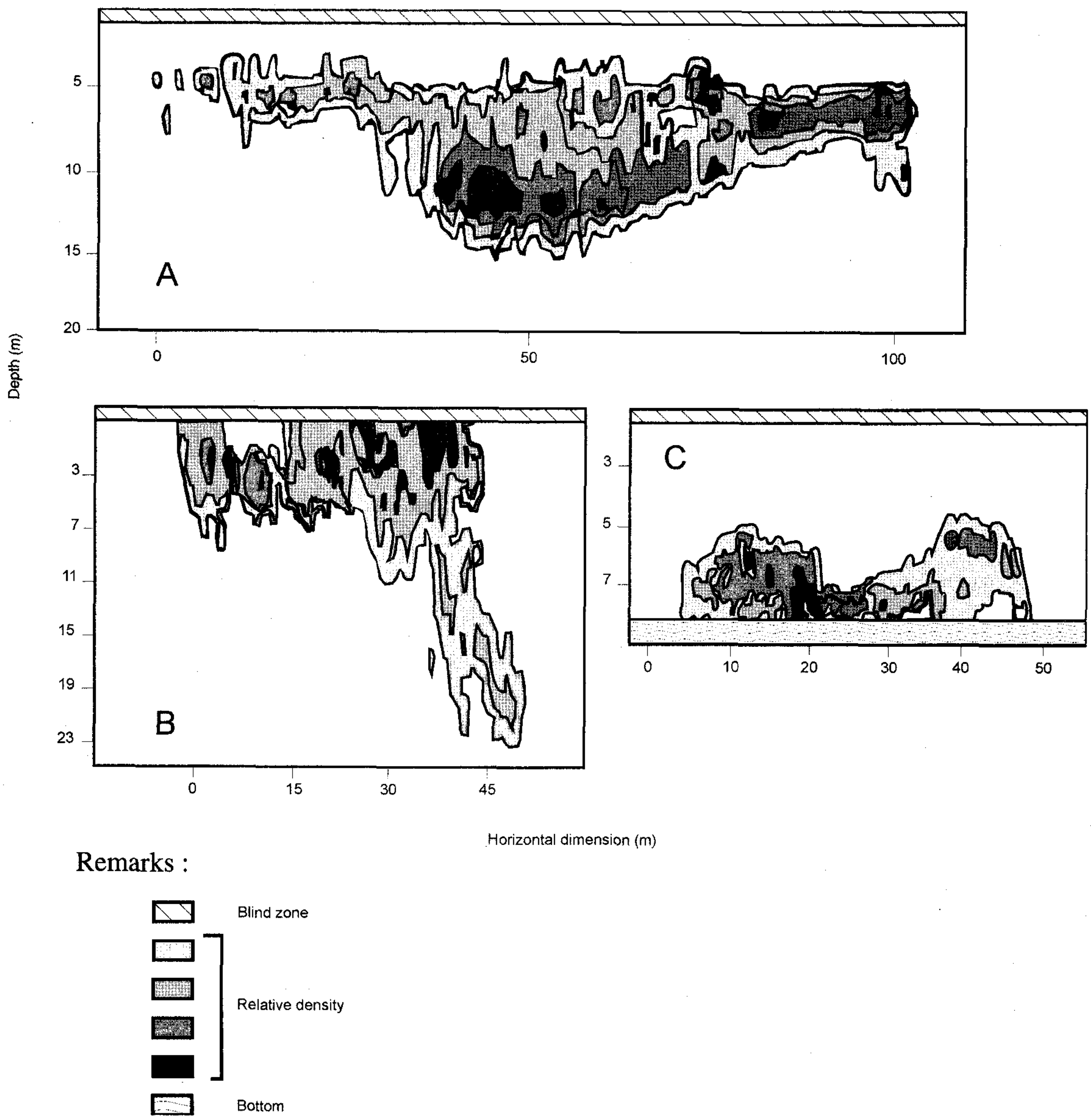

Figure 1 **Density heterogeneity in three tropical Clupeid schools observed by vertical sounding (Freon *et al.*, 1992).**

Gambar 1 **Heterogenitas kepadatan pada tiga pengelompokan Clupeid tropis (Freon *et al.*, 1992).**

A. *Sardinella aurita* (Venezuela)
B. *Sardinella maderensis* (Cameroun)
C. *Harengula sp* (Martinique)

A certain number of assumptions about the dynamic and spatial function of schools, that can explain this obvious contradiction, were based on these observations. In fact, this should explain the steadiness of inter-individual distances and the heterogeneity of the school. We present here the "stretch-split" (Fréon *et al.*, 1992). The schools in their unity represent a "spongy tissue" formed by fish, around the vacuoles of various sizes. On non-stress situation, fish show individualistic behaviours and the inter-individual distances vary relatively, continuously with less visual contact. In the phase of moving or stress, the fish use this regular spatial structure as often described, with polarization and synchronization of the reactions. In this matter the vacuoles form in a very visible manner (Fig. 2), due to the synthesis of the two basic tropisms :

- Each fish tends to keep a constant distance from others. In this situation, for one reason or another, appear a slight "stretch" inside the school tissue. The fish situated at the break point choosing to remain with one or the other neighbour, but does not let the distance to the nearest neighbour overstep an alert threshold. The stretch comes then to a wrench then to an empty space, that will not be filled up by the following fishes. In fact, an empty space represents a dangerous zone for individuals. It often motivates a decrease of inter-individual distances, thus an extension of the empty space, until the moment it forms an important space that is passed over by the totality of the individuals.
- This wrench that, if alone could be a cause in preventing schools formation, is compensated by the fact that the fish shoals, or micro-schools, have a tendency to recast inside a more important unity. There is a gregarious reassemble, as soon as it is possible. This behaviour explains why, once the empty space (wrench) has been shaped, the group of fishes bordering this volume, as far as they keep visual contact, tend to be closer. In a second time, space then tends to decrease because of banks attractions, and the vacuole is then formed. These hypotheses have been successfully tested by simulation of artificial life.

General characteristic of schools

Schools abide by a series of behavioural and functional features. To summarize, a school is :

- a temporal gathering of individuals sharing common characteristics, altogether in anatomy, physiology and behaviour,
- a spatial structure constructed from basic behavioural reactions,
- a dynamic structure the function of which (in term of evolutional adaptation) should be essentially anti-predatory (resulting of confusion for a predator because of synchronous reactions of unrecognizable individuals).

Furthermore the school structures vary according to different factors :

- The biological rhythm; the school structures vary in cyclical way, particularly on 24 hours cycles. Generally the structure is much looser, even absent at night and more concentrated at day. This observation has been renewed several times ever since, see Fréon *et al.* (1993; 1996) for more. This basic sketch undergoes several exceptions. The light impact appears to be determining : according to the tearing diagram hereafter, it can be seen that, if inter-personal contact is both supported by visual and acoustic stimuli (pressure field created by fish moves and detected by their horizontal line), the border rapprochement of the vacuole, even of "micro-schools" is essentially allowed by visual contact. When luminosity decreases, these rapprochements become more difficult, and the fish groups "lose contact." The school decreases notably in size. If the illumination completely disappears, the individual contact becomes difficult to keep and the dismissal becomes total (case of full moon periods). The fish are also capable to receive an illumination intensity extremely weak (Glass *et al.*, 1986), so the school can preserve itself during the night, when the moon is present, even by cloudy skies.

- Predation is also an important factor of the structure change. Soria (1994) has shown that the school internal density was directly a function of presence (contraction) or absence (expansion) of predators. A given school is subject to changing its internal density in a very short time. It has also to be noticed that schools, undergoing predators, show a strong tendency to break off into sub-units, which, as long as the predators pursue them, do not tend to reassemble (Fig. 3).
- Finally physiological variations (e.g. alimentation, reproduction) are also changing factors of the structure, cohesion and school mobility.

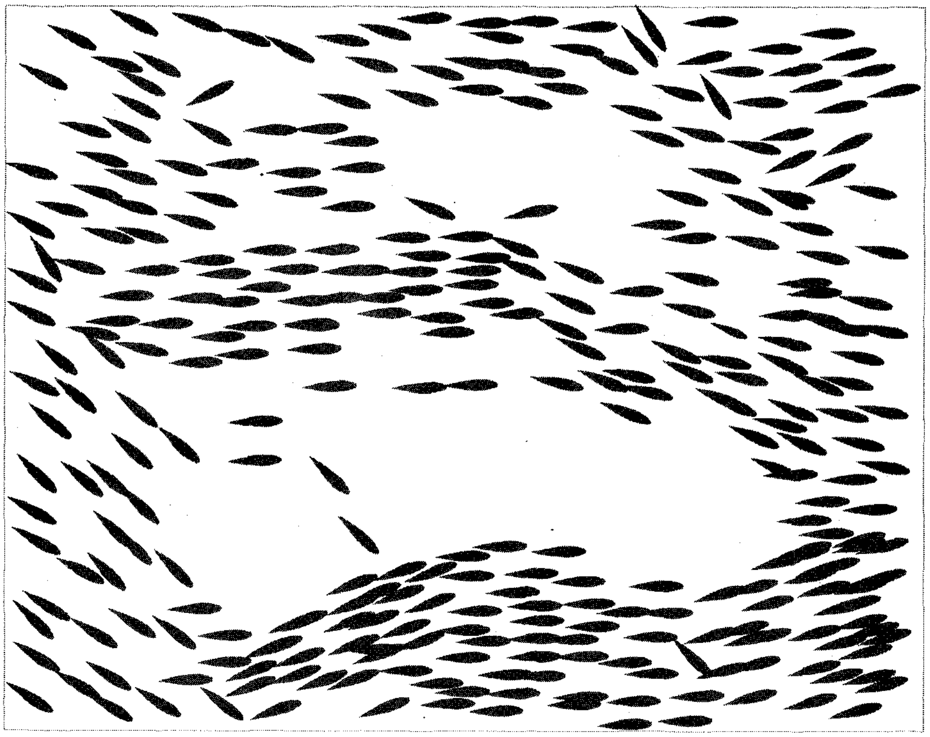

Figure 2 **Appearance pattern of vacuoles in a school from visual observation (*Harengula sp.*, Martinique).**

Gambar 2 **Pola penampilan "*vacuoles*" di dalam kelompok ikan dari observasi visual (*Harengula sp.*, Martinique).**

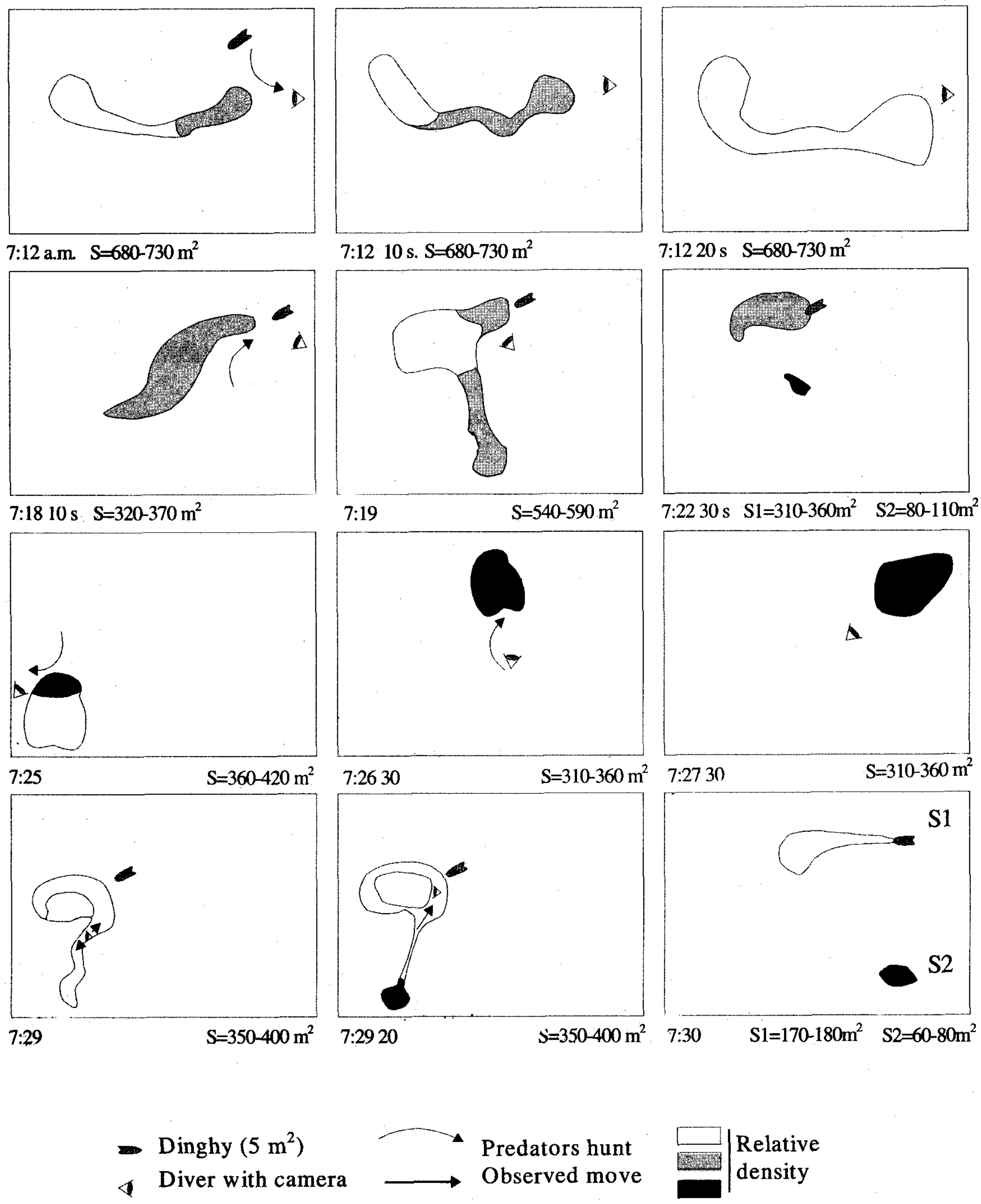

Figure 3 **Pattern modifications of *Harengula sp.* school hunted by predators (bonitos), from aerial observations. The frames are fixed (for each of 4 series of observations) and allow to measure the displacement of the schools.**

Gambar 3 **Modifikasi pola *Harengula sp.* yang sedang diburu oleh predator-predator (bonitos) dari pengamatan udara. Setiap gambar ditetapkan berdasarkan 4 seri pengamatan, dan memungkinkan untuk mengukur pergerakan kelompok ikan.**

The most important limiting factor, for any in site study on marine population, is the fact that water is an environment that can be considered as opaque. In the best studies, visibility does not exceed 50 metres, and "efficient" visibility about 20 metres. Besides, underwater observation is technologically expensive, and its use for so small sampled volumes has to be righteously justified.

Acoustics methods, presented elsewhere, solve the most important part of the problem of measurement. The sonars are instruments of small size (relating to the range they cover), with a satisfactory capacity, and even more, the signal received is easily digitized and stored.

Concerning the pelagic schools, basic devices consist in two types : vertical sounder and sonar.

Vertical Sounder

It provides three data types for the study of school : echogram, density measurement (echo-integration) and geometric parameter measurements of schools.

- *Echogram.* This is a retranscription on a visual support (paper or video screen) of information supplied by acoustic signal. Echogram, that was the first representation of acoustic information, is still a very useful result, in the fact that it points out, for example, the typology setting and the school classifications by type. By now, these classifications and these particular typologies are done manually, because the processing system and image analysis are not fulfilling enough to extract coherent parameters from echogram, due to the geometric variability of this later (Petitgas and Levenez, 1996; Fig. 4).
- *Density measurement.* The echoes received, after a proper mathematical processing, are proportional to absolute fish density. Therefore, it is possible, by "echo-integration," to know precisely the density, even the biomass of a particular school. This measurement is especially important for abundance measurement and for the follow-up of fishery. The knowledge of school density shows several interest. It points out, at the first moment, a general information about total biomass of pelagic population. It is also a way to an automatic identification of the species, based on the fact that every species has a specific acoustic response, due to their individual anatomy (example : mackerel *Scomber scombrus*, which does not have swimbladder, shows a quite lower acoustic density than the other species), or finding itself, at the moment of the observation, within a state of particular density (Massé, 1996; Massé *et al.*, 1996).
- *Geometric Parameter Measurement of Schools.* Schools present specific geometric characteristics : diameter, perpendicular height, surface of the vertical section on echogram, roughness, etc. This information on every school is nowadays available through proper processing software, such as MOVIES B (Weill *et al.*, 1993). Furthermore their situation, inside the water layer, is also an essential information, as well in terms of stock types (pelagic, demersal), as dynamic features of behaviour or the possibility of school avoidance measurement along the ship's route. This information is also routinely obtained via the same software.

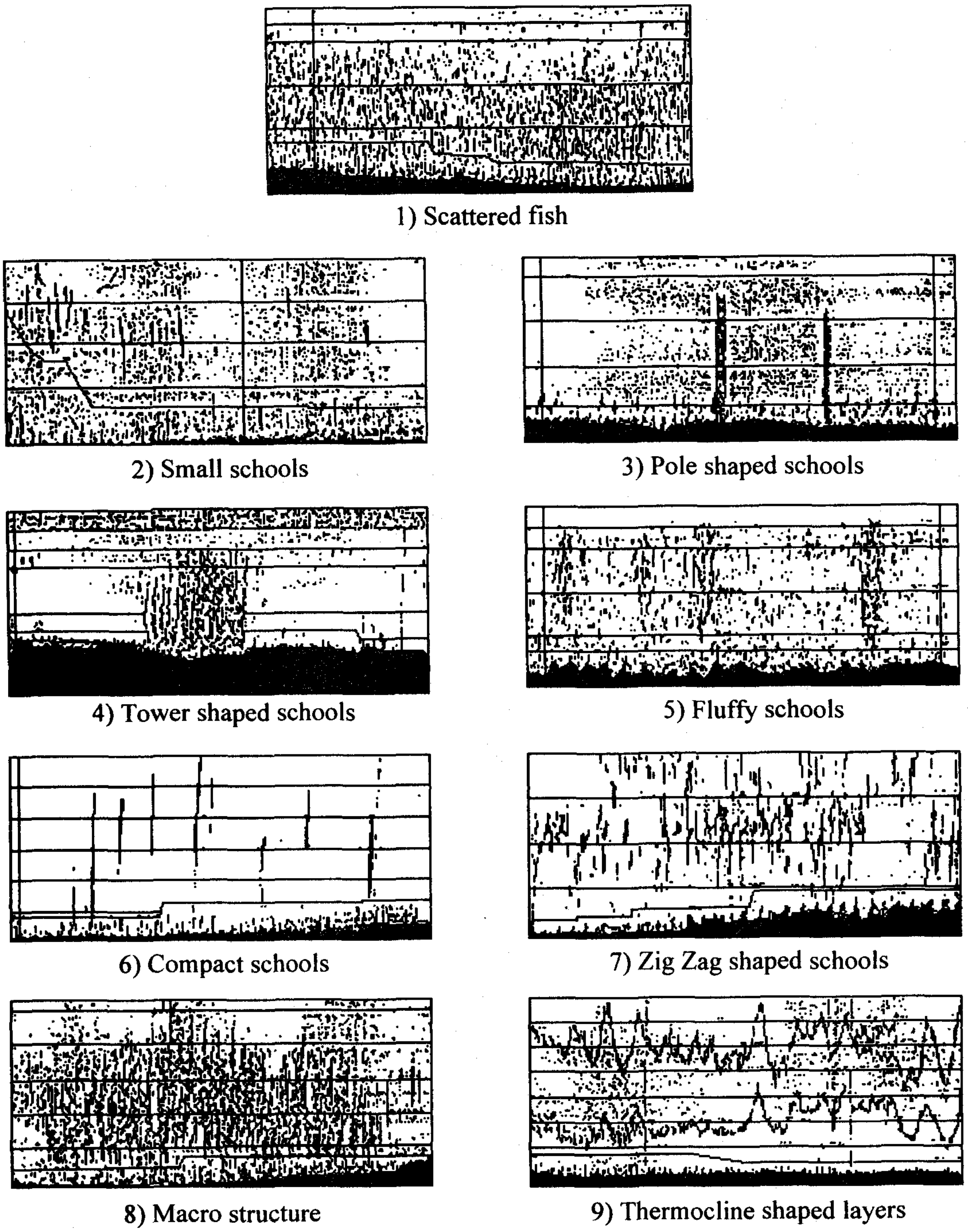

Figure 4 **Pelagic school typology in Senegalese waters (Petitgas and Levenez, 1996).**
Gambar 4 **Tipologi kelompok ikan pelagis di perairan Senegal (Petitgas dan Levenez, 1996).**

Penjelasan :
1) Ikan terpencar-pencar
2) Kawanan ikan kecil
3) Kawanan berbentuk tongkat
4) Kawanan berbentuk tugu
5) Kawanan bersifat lembut
6) Kawanan menyebar memenuhi ruangan
7) kelompok berbentuk zig-zag
8) Struktur makro
9) Lapisan-lapisan berbentuk seperti termoklin

Sonar

At the beginning, the term sonar (SOund NAvigation and Ranging) named every aquatic acoustics transmitter-receiver. Then, it was given to vertical sonar (designed to depth measurements) the name of sounder. At present, sonars show 2 types of tools : the sonar with a single beam and the multi-beam sonar. Only the last one will be described here, because the evolution of this device is almost of universal use nowadays. We present here two kinds of multi-beam sonar :

- *Long range low frequency sonar*. Generally it is a "omnidirectional horizontal" device, which frequency is relatively low (lower than 38 kHz), with a range of more than one kilometre; it is used by the fishermen to locate, approach and capture a school. These sonars generally have opening beams of about 6 to 15 degrees, covering 360° of the field. This kind of sonar is also used by very few scientists (Misund, 1993; Diner et Massé, 1978; Petitgas *et al.*, 1996), because information obtained are difficult to process. Nevertheless, the informations provided are numerous, and concern essentially the inter-school relations (distance between schools, regrouping formation, relation between the inter-school distance and the school size, etc.) and the behaviour (rapidity and sense of moving, natural and induced by a vessel in route or fishing, etc.).
- *High frequency sonar*. Identical to the previous one, it transmits within quite high frequency range (above 300 kHz in general), in a shorter range (below 200 m) and on a more limited sector (90 to 120 degrees). In return, the definition is by far better : the beams are in the degree accuracy, and the wavelength (the duration of transmission) is shorter. This system, initially created for three dimensions mapping of the bottom (sonar scanning), is of recent use in Halieutic, and information provided are still difficult to analyze by lack of adapted software. The sonar is used in non conventional mode (Fig. 5); the basic observation plan is vertical and perpendicular to the ship's route. In this way, it sweeps a vertical profile, going from the surface to the bottom, until a distance of about hundred metres from the ship. Furthermore, the volume is almost exhaustively observed on a high rate (several transmissions per second) along the ship's route. We obtain then an exhaustive view of the number and the position of the schools along the route. Also are provided their real size and structure, in three dimensions.

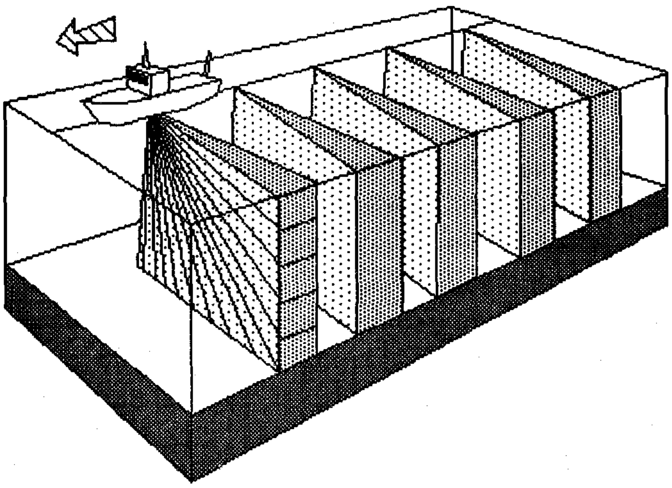

Figure 5 Use scheme of the multibeam high frequency sonar (Soria *et al.*, 1996).
Gambar 5 Skema penggunaan multibeam sonar frekuensi tinggi (Soria *et al.*, 1996).

Images obtained by scientific devices are misleading, because they seem to be an exact representation of the structure observed. But, due to geometry of acoustic beams, they give a very different image from visual observations, for instance satellite images. Indeed, acoustic transmission is cone-shaped, which becomes wider and wider as it moves away from its source. The volume observed is then dependent on the transducer's distance, and the echoes are averaged in volumes increasing with the depth. But the essential sources of the bias are of another order and two types can be brought up, as following :

Bias linked to acoustic technique

They are directly linked to the physics of the acoustics wave and to their spreading. We will give only one example : the phenomenon of the "acoustic shadow." The impact of this phenomenon was described at the beginning of the technical application of Echo-Integration by Röttingen (1976). When schools are compact and/or of a great size, the signal is entirely reflected before entering through the entire school. Only the superficial layer produces an echo, and the total biomass of the school is then under evaluated. Röttingen (op.cit) has shown on fish in cage that, beyond about one hundred fishes per square metre, the effect of the acoustic shadowing was perceptible (Fig. 6). This is for theoretical measurements, and it is important to know if these densities are present in the nature or if these values have to be corrected. A verification example is given on Figure 7 (Gerlotto, 1993), where the schools measured during a survey in Venezuela are classified, function of their densities and their height (those two parameters can induce acoustic shadow). The correction abacus has been calculated according to equations established by Foote (1983; 1984) and Olsen (1990). It is there obvious, if it is true, that the bias owed to acoustic shadows are seen on some school. The difference with the measured biomass does not reach more than 1%, that is neglectable compared to other sources of bias.

The interest of such an example lies in the fact showing that bias linked to technology can be, if not controlled, at least acknowledged, and their impact on evaluation evaluated. More often, acoustic methods bring along their own methods of correction.

Bias linked to fish behaviour

Generally, these are the most important and the most problematic ones. They are evaluation's error due to an inadequacy of prospecting method in a given environment or to individual reactions of fish. Here are shown three examples.

- *Diving behaviour.* An experiment presented by Gerlotto et Fréon (1992) on some schools, individualized in the Cariaco Gulf (Venezuela), had shown that schools have a coordinated diving reaction when a ship passes over them. The experiment consisted in observing and recording a school with a vertical sounder in natural situation or less distortable as possible, then to observe the same school in a classic prospecting situation, meaning disturbed by the passing ship. For this, authors placed a portable sounder in a rubber dinghy, and stood in front of the visible route of a school, for which they were waiting. Once the school passed under the rubber dinghy, the research vessel (N/O Nizery, 25 m long) then passed, with a prospecting speed, on the school. The successive school positions plotted, showed that the school dived under the ship, in such a way that the more superficial the school initially was, the deeper it dived. Further, the school showed a change in structure, the upper part being more dense than within the deepest layers. This differential behaviour fits the result of previous experiences realized in Norway (Olsen *et al.*, 1983). The observations on bigger number of schools, performed with high a lateral frequency sonar (Soria *et al.*, 1996), showed also that the school, situated at the vertical of the ship, are in average more profound than the observation aside the vessel. This observation showed that the average position of the school, within the water column, is biased by its diving behaviour.

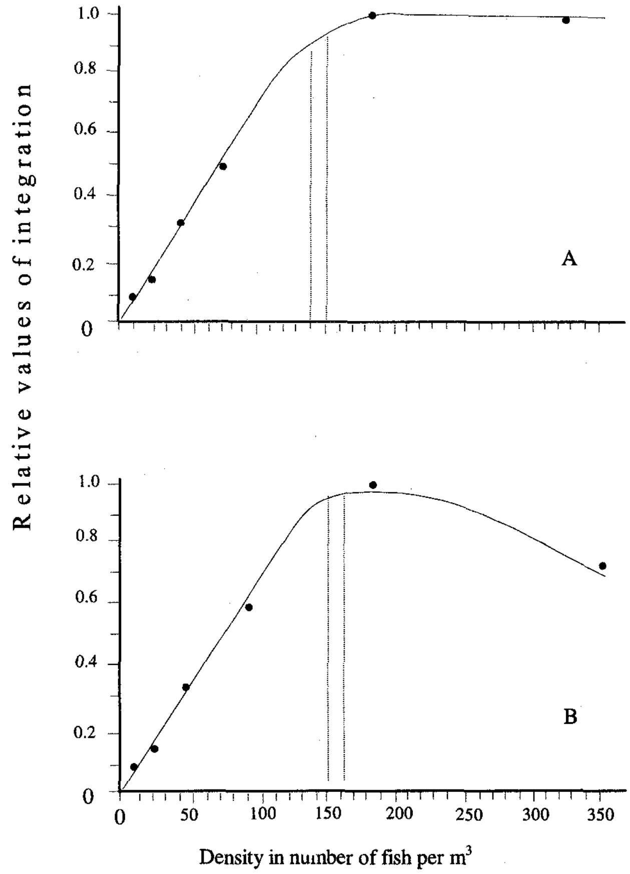

Figure 6 Evidence of acoustic shadow effect on caged *Pollachus pollacus* (Röttingen, 1976). A : 0.1 ms pulse length, B : 0.6 ms pulse length

Gambar 6 Bukti dari efek *acoustic shadow* pada *Pollachus pollacus* dalam kurung (Röttingen, 1976). A : 0.1 ms panjang pulsa, B : 0.6 ms panjang pulsa.

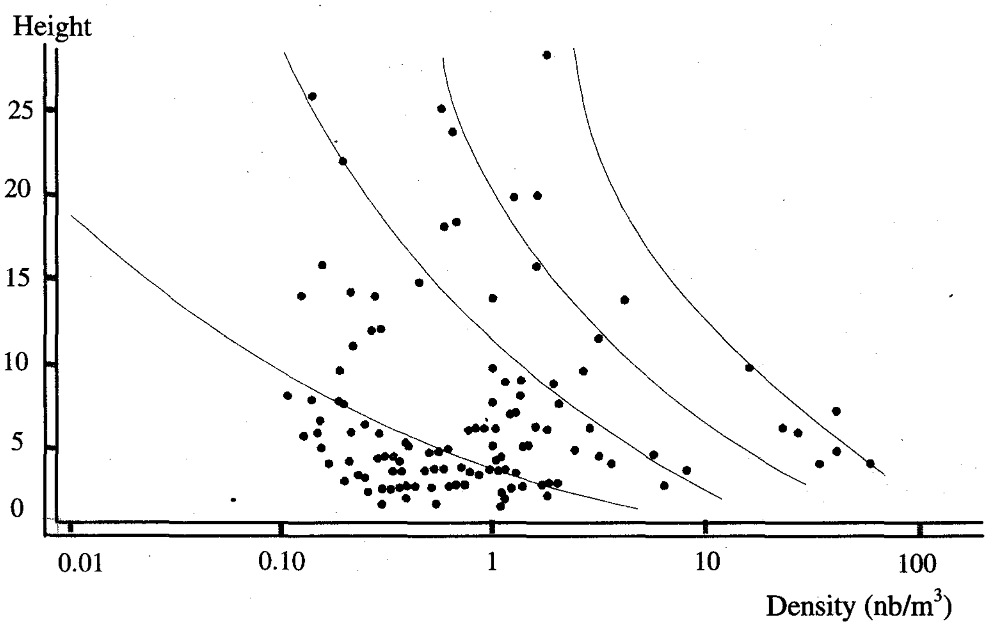

Figure 7 Density and height relationship in schools (ECOMAR 1). Evaluation of acoustic shadow correction factor (Gerlotto, 1993).

Gambar 7 Hubungan densitas dan ketinggian dalam kelompok ikan (ECOMAR 1). Evaluasi faktor koreksi *acoustic shadow* (Gerlotto, 1993).

- *Lateral avoidance.* Misund and Aglen (1982), Diner and Massé (1987) have studied this lateral avoidance phenomenon, by following pelagic schools with a low frequency panoramic sonar. These scientists also described school dynamics and asserted that lateral fleeing could lead to break the school in two parts. Gerlotto and Fréon (1988), from several sources (Misund, 1990) analyzed behavioural pattern and stimuli sparking this fleeing, thus showing that the sonic spectrum of the boat showed tight correlation to direction of avoidance (Fig. 8). Soria *et al.* (1996) compared mean densities to the number of schools per distance unit at different range from the boat (including vertical), using high frequency lateral sonar. Their results clearly show that schools are more numerous at remote distance from the boat than under the way. From those observations, authors proposed a "double wave avoidance" pattern (Fig. 9). It is clear that this behaviour leads strongly to underestimating ponderal assessment of pelagic stocks.

- *Natural rhythms.* It was previously said that schools shape and part, according to day/night alternance, what for acoustic observations leads to 2 consequences.

  ⇒ descriptions of detection types on a given area differ according to day or night achievement : data collected on extended areas have to be parted between day or night data. Actually, It should not only be easy to link day detections to these of the night, but furthermore the great concentration of fish, by day, make their detection more difficult : dense gathering within restricted volumes, compared to the survey area, can require a survey pattern different from the night survey, when fish are scattered and their dispatching more homogenous.

  ⇒ fish reactions are very different according to whether they are schooling or not. On dispatching time, fish show two remarkable features : they have a restricted avoidance behaviour that is favourable for observations. They are not polarized, and their mean angle to horizontal axis is greater. Some scientists (Buerkle, 1983; 1987; Aoki and Inagaki, 1982) proved that the mean angle was 10 degrees more to that it is by day. Given that echoes reflected by individuals are very sensitive to this angle (Nakken and Olsen, 1977), one can see that this factor is rather unfavourable.

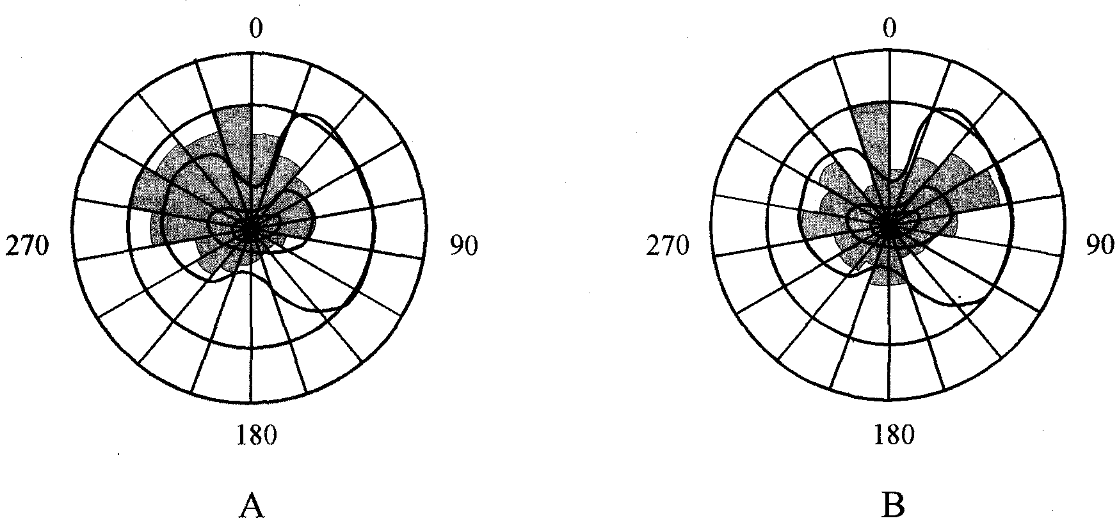

Figure 8 **Vessel noise and school lateral avoidance relationship (Gerlotto and Freon, 1988). Sound pressure in bold line, avoiding school percentage by sector in gray (data from Misund, 1990).**

Gambar 8 **Hubungan suara kapal dan penghindaran secara lateral kelompok ikan (Gerlotto dan Freon, 1988). Tekanan suara digambarkan dengan garis tebal, sedangkan persentase penghindaran oleh kelompok ikan dalam bidang berwarna abu-abu (data dari Misund, 1990).**

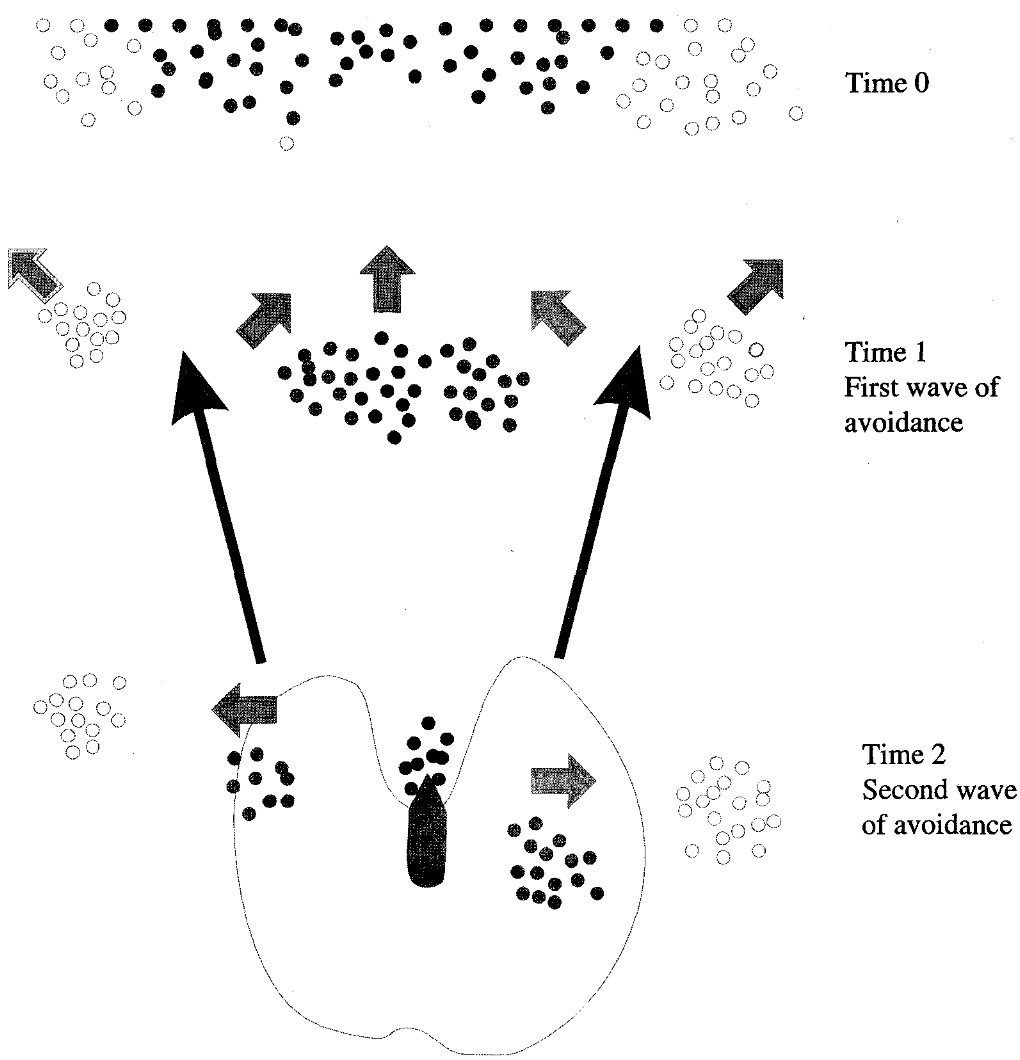

Figure 9 The double wave avoidance of school in front of a vessel (Soria *et al.*, 1996).
Gambar 9 Penghindaran *double wave* kelompok ikan di depan kapal (Soria *et al.*, 1996).

There are other rhythms that can show non neglectable influence on those evaluations. Particularly, wide migrations. The impact of these cycles can arise in several ways. At first, it is obvious that an assessing survey, that would not be carried out on the totality of the potential living area of a stock, should be cautiously planned, so that the stock can be found within the time frame of the survey, else assessing will not make sense. Secondly, if it is not possible in period of stability of the stock, it has to be taken into account the direction and motion of migration related to the ship ones. A survey achieved all along a migration can lead to overestimation, since the boat has counted several times the same fish. On the contrary, a prospect, carried out on the reverse way, underestimates a stock.

Errors on evaluation

A quite complete study of errors, concerning biomass evaluation by acoustic surveys, had been published by Simmonds *et al.* (1992). Hereafter is a synthetic table of the measurements from those authors.

Table 1 Evaluation of the different errors sources (from Simmond *et al.*, 1992).
Tabel 1 Evaluasi beberapa sumber kesalahan yang berbeda (dari Simmond *et al.*, 1992).

Uncertainty source	error	bias
physical calibration	2 %	5 %
transducer moves	-	0 to 10 %
microbubbles attenuating	-	0 to 10 %
hydrographic conditions	2 to 5 %	-
TS	5 %	-
Species identification	-	0 to 20 %
spatial sampling	10 to 25 %	-
migrations	-	0 to 5 %
day/night behaviour	0 to 10 %	-
avoidance, behaviour	13 to 57 %	

This table shows that schooling behaviour, to which are linked day/night behaviour, spatial sampling and avoidance, is directly responsible for an error from 25 to 92%, and a bias of 0 to 5% in biomass assessment. The rest of acoustic features, by their own, is responsible for an error of 9 to 14% and a bias of 5 to 45%.

Nevertheless, those results must be relativized, taking into account these two statements. First, this table is just an indication on a range that has to be adjusted for a given survey. For instance, it was seen that acoustic shadowing, potentially important, does not exceed 1% of error in the case of our results. On the other hand, it has to be noticed that, if the acoustic methods include numerous error sources, they generally are able to assess these errors, then to set methods to correct them. The case of migrations is a good example : using a relevant strategy, MacLennan and Simmonds (1991) have been able to totally erase the error due to this behaviour. Generally speaking, it is estimated that total error on a prospecting is about 30%.

Interpretation errors

It has been seen before that schools have a vertical fleeing behaviour, that make their mean position on echograms several metres lower than their natural position. This is not a neutral point, as it can lead to misguiding conclusions on catchability of those fish. Here is a special and clear example : in the eastern area of Venezuela, especially in the Gulf of Cariaco, where has been precisely recorded this diving behaviour, fishermen detect schools from a coastal hill, from the perturbation the fish create at the surface, or from the presence of associated fauna (e.g. birds). Then they catch fish thanks to gill nets. Since schools have dived before being recorded by the echo-sounder, an acoustic observation can lead to think that a great part of stock is not catchable because deep, so the stock is naturally protected, whereas the reality can turn out to be very different. In the case of the Gulf of Cariaco, it has been noticed during a survey that only 14% of schools were located to a depth less than 10 m, so potentially catchable, according to their bathymetric position not corrected. If a correction of the diving effect is done, this proportion can reach 46% (Fig. 10).

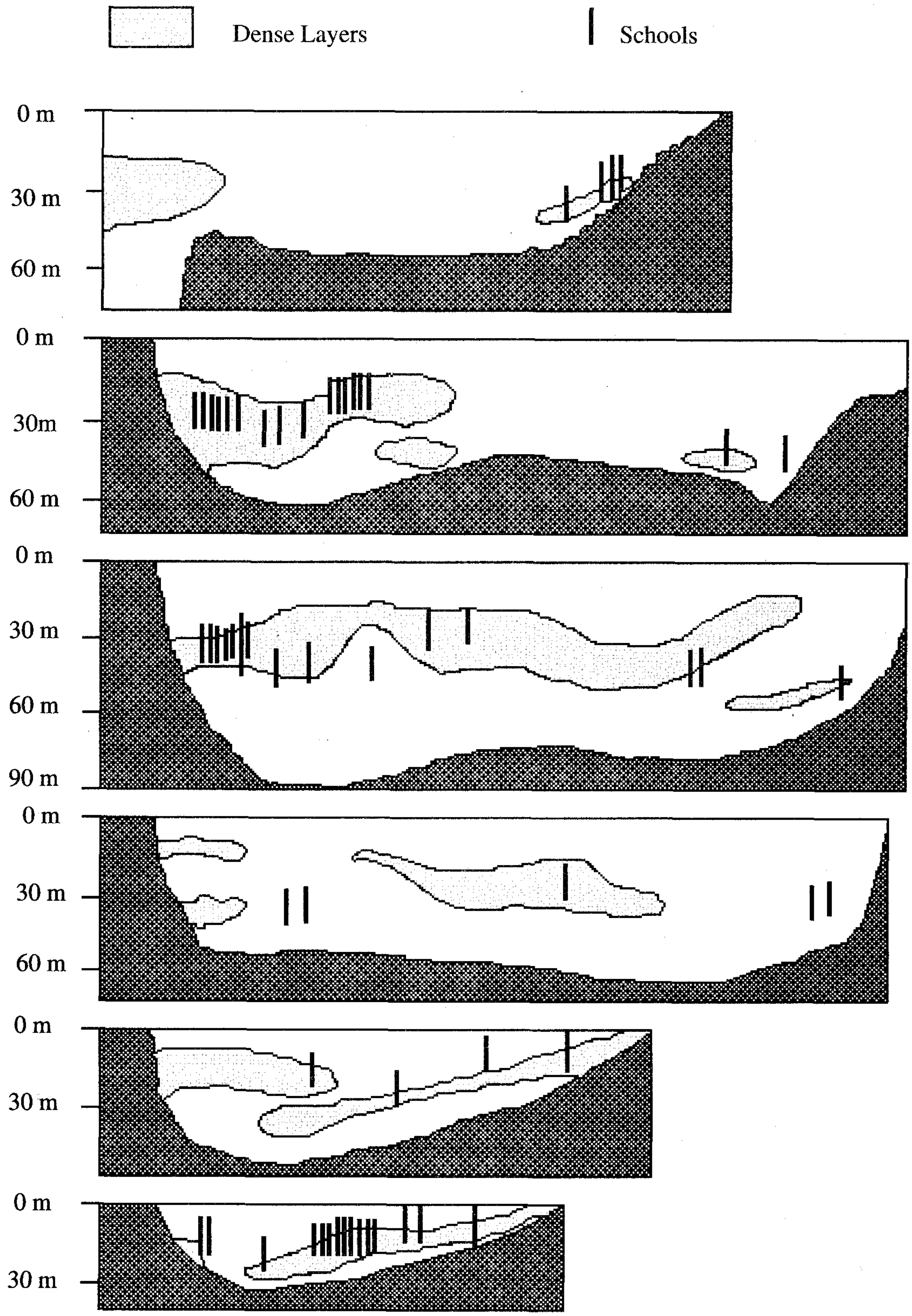

Figure 10 **Vertical distribution and pelagic fish layers along 6 transects in Cariaco Gulf, Venezuela (Gerlotto, 1993).**

Gambar 10 **Penyebaran vertikal dan lapisan ikan pelagis sepanjang 6 jalur pelayaran di Teluk Cariaco, Venezuela (Gerlotto, 1993).**

Sampling and identification

One of the main weaknesses of acoustic observations lies within the fact that at each species has to be allocated a proportion of the calculated biomass. This is usually achieved through identification fishing. Still, fishing samples are often strongly biased by gear selectivity and school behaviour. Thus, we established (Gerlotto, 1993a) that most of identification trawlings were more similar to a draw of a given feature than a proportional sampling of all features. Table 2 gives, for example, the proportion of round sardinellas (*Sardinella aurita*) in identification catches, for a survey in Venezuela (ECHOVEN 2). The binary feature of this sample is obvious, whereas pelagic fish in this area are composed of about thirty species, only of Clupeids and Engraulids. On 27 trawlings, only 5 have proportion values above 5% and below 90%.

Table 2 Proportion of catches in sardinellas in pelagic trawlings of ECHOVEN 2.
Tabel 2 Proporsi hasil tangkapan ikan sardin dengan trawl permukaan ECHOVEN 2.

N° of trawling	Proportion (%)	N° of trawling	Proportion (%)
1	66.7	16	78.5
2	0	17	1.2
3	0	18	99.0
4	99.5	19	100.0
5	75.0	20	98.6
6	90.0	21	0.6
7	95.3	22	98.6
8	0	23	-
9	0	24	0.6
10	0	25	99.7
11	0	26	98.0
12	0	27	-
13	0	28	0
14	20.0	29	58.3
15	3.7		

It is then obvious that gregariousness has a real impact on fishing. Profitable for industrial fishery, it is a handicap for scientific identification fishery : in a certain way, the first school caught alters the results of proportion in favour of the species of which it is composed. It becomes then almost impossible to determine both the proportion of the species and the mapping of their preferential location.

We have been able, after all, to better notably this point, by taking into profit the gregarious feature of fish, by using a stratification method called "acoustic population." The principle consists in stratifying a zone in regular strata (rectangular, for example) then to carry out a multivariate analysis and a hierarchic ordering of strata from behavioural features of the community. The example given (Gerlotto, 1993b) shows the results of such analysis on the same data than formerly introduced (ECHOVEN survey, Venezuela). Parameters given are school types (pelagic or demersal), day/night behaviour (ratio of biomasses on number of schools night/day), spatial scattering features, etc. Results are shown on Figure 11. They assert that we have been able to map several homogenous zones allocated to the main species or groups of species, from the results of identification or professional fishing.

Acoustics and management

Up to now, implication of acoustics in management simply consists in providing biomass values, either global or by cohorts, in order to calibrate population dynamics models (especially VPA). The fact that pelagic fish are generally gathered into schools, yet allows, along with the evolution of acoustic techniques, to provide managing tools for a more elaborate level. The spatial behaviour of pelagic population shows several impacts on the dynamics of an exploited population, that has to be studied. Here are proposed four of them :

- Impact of spatial scattering. Whether a population shape in a type of spatial structure or another, at a small scale (school), middle or big scale (cluster, population), its accessibility in terms of probability to meet the population (fishing or evaluation) can vary. This statistic link between distribution type (histogram and density location) and catchability can be seen from acoustic data and simulations.
- Impact of small scale structure variability. Schools are able to successively shape into different types of form. These forms, as in the former case, can influence both vulnerability and accessibility. A typology of shapes and a dynamic description of changes linked either to biological rhythm, or to presence of fishermen, or to ecological conditions in the environment (food, predation,...) can thus be carried out from echograms.
- Impact of environmental conditions. They can lead to an increase or a decrease of catchability. Furthermore, relations between different trophic levels and environment can lead, directly or not, to favourable or unfavourable conditions for exploitation in specific zones. Precise links between environmental data and dispatching and types of structure are as well key points, allowing to understand the reasons of presence or absence of stocks. It has to be noticed that the impact of environment on biomass is not studied there, but on spatial structure.
- Impact of gregariousness. Fishermen use more and more attraction and concentration devices in reduced areas, in order to catch them (DCP, shipwreck, etc.). Those mechanisms are not well understood, though allowing an important part of catches. Understanding their functioning implies to establish ethologic systems, happening during the ontogenesis and leading to these reactions of attraction and fixation of fish around an artifact.

CONCLUSION

Gregariousness is a strong component of spatial behaviour of pelagic fishes. Even if such behaviour can be found in other animals' groups, and especially birds and some insects (crickets, butterflies...), it is in this phylum that the formation of great non hierarchized and polarized gathering is the most spectacular. This behaviour requires a special adaptation of scientific studies, as far as it produces some types of spatial scattering that are particular for which, within other, usual statistical methods are unusable. In turn, adaptation of methods of analysis to this behaviour allows to take some advantages (identification). Man is not only a searcher : it is also the most adaptable predator of the whole biosphere. The fisherman has also taken advantage of this behaviour to set catching methods of great efficiency. Paradoxically, the gregarious behaviour, that is theoretically considered as an effective "anti predator" tool, turns against the species of which adaptability as well in terms of learning as of evolution, is infinitely less than the human's. Are those huge pelagic stocks endangered by overexploitation ? It is yet too soon to answer. One begins to better understand the other role of these huge concentrations of fish, that would not only be an answer to predation, but also would allow a more effective adaptation to environment variations. Dramatic drops of the number of these stocks, especially in the case of Engraulids and Clupeids (North Sea Herrings, Sardines of Japan, California, Chile, Sardinellas of Ghana, etc.) have often been followed by recovering, not less spectacular. Gregariousness could thus also have an evolutive meaning more important than its instantaneous role of response towards predators.

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Discussion

(Chairman Dr. Fatuchri)

Mr. Sihotang

Q : - The avoidance error is from 0 to 50%; How can this interval error be found ?

A : - I will give you two answers :

1. Avoidance can be very important. For example, according to the Norwegian, only 20% of the biomass are estimated. Fish avoids for two reasons : the first one is the noise and the second one is the light at night. That is why we recommend to switch off the lights. If not, you will have different estimations of the biomass.
2. The percentage of avoidance depends on the fish and the vessel. In some parts of Venezuela, there is no avoidance. We have the same values at day and at night. In other places, avoidance can reach a factor 2. How is this percentage calculated ? It depends on the area. You have to make your own experiments to estimate the factor that is suitable.

PREDATORS AND PREYS : AN ACOUSTIC APPROACH

E. MARCHAL, E. JOSSE, A. LEBOURGES

ABSTRACT

Predators are seeking for congregated rather than scattered preys, and are schooling themselves most of the time. Studying relationships between predators and preys needs to identify them. Classical methods of investigation, such as the use of different kinds of net (plankton, midwater trawl) with a regular sampling grid, often fail to succeed in catching them, due to their very heterogeneous distribution. In contrast, acoustics allows us to « see » and to study them, thanks to the very good transmission of sound in the water. A good example of the way acoustics could be used to study predator-prey relationship is provided by a tuna fishery in the Equatorial Atlantic which exploits a seasonal tuna concentration. It was assumed that tuna find here an abundant food, supported by the very high percentage of a mesopelagic fish, *Vinciguerria nimbaria*, found in their stomach contents. However this fish is known as a dial migrator, diving to deep waters during daytime, where tuna could not catch them since they are view-feeders. Acoustic detection has proven that, in this case, this small fish could stay in the surface layers, aggregating in small schools at the thermocline level. In addition, acoustic tagging has shown that tuna were staying most of the time at this particular level. Finally, acoustic estimation of the packing density and the volume of these schools allows us to assume their actual role into the daily feeding of tuna.

KEYWORDS : predation and feeding, tuna, mesopelagic fauna, dial migrations, acoustic detection.

ABSTRAK

Sebagian besar tingkah laku pemangsa cenderung mencari mangsa yang mempunyai sifat berkelompok daripada mangsa yang sifatnya terpencar. Suatu telaah tentang hubungan mangsa dan pemangsa perlu diteliti secara terperinti. Penelitian dengan metode klasik seperti halnya dengan penggunaan berbagai macam jaring plankton maupun trawl pelagis melalui pengambilan contoh secara teratur sering kali menemui kegagalan dalam upaya mendapatkan data tersebut yang disebabkan oleh sebaran keberadaan yang sangat heterogen. Sebaliknya penggunaan metode akustik dapat memperlihatkan keberadaannya melalui proses pancaran suara dalam kolom air. Suatu hasil pengamatan yang sangat baik melalui metode akustik yang dapat bermanfaat bagi penelitian hubungan mangsa dan pemangsa telah dibuktikan pada perikanan tuna di perairan Ekuator Atlantik dimana kegiatan penangkapan tuna dilakukan secara musiman. Telah diduga bahwa keberadaan tuna tersebut berkaitan erat dengan melimpahnya makanan yang ditunjang oleh sangat tingginya keberadaan ikan mesopelagis, Vinciguerria nimbaria *sebagai preferensi makanan pada isi perut tuna tersebut. Jenis ikan mesopelagis ini dikenal sebagai jenis yang melakukan ruaya tegak harian, yang berada di perairan yang sangat dalam pada siang hari dimana tuna tidak dapat memangsanya. Pelacakan melalui teknik akustik menunjukkan bahwa jenis ikan berukuran kecil berada dilapisan permukaan dan berkelompok kecil pada lapisan termoklin. Ditunjang oleh hasil penelitian melalui teknik penandaan akustik (acoustic tagging) terlihat bahwa tuna sebagian besar waktunya berada pada lapisan ini. Akhirnya, pendugaan akustik melalui pekiraan kepadatan (packing density) dan volume kelompok ikan ini dapat dijadikan dasar peranan keberadaan jenis ini pada makanan harian ikan tuna.*

KATA KUNCI : pemangsa dan makanan, tuna, fauna mesopelagis, ruaya harian, akustik.

The predators must find their preys : they have advantage to seek for congregated rather than scattered preys, from the view point of energy consuming. Generally, the size of the preys is smaller than the size of their predators and these preys belong to a lower trophic level. If we take tunas as an example, they eat especially small fish which themselves consume essentially small shellfish such as copepods. What is true for the terminal predators is also true for their preys which behave usually also as predators, even if they may appear less active : so those small fishes will seek for layers and swarms of the zooplankton. We can practically say that the zooplankton also seek for concentrations of phytoplankton on which they feed. Certainly, the movements will be of much less amplitude and they will be mainly characterized by aggregations where the phytoplankton itself is concentrated by physical structures such as frontal zones, thermoclines or peripheral parts of upwellings.

So, whatever the trophic level concerned, we observe a great heterogeneity in the spatial distribution of organisms composing this level. Such an heterogeneity corresponds with a so-called « contagious distribution » by the statisticians and which, in the field of biology and behaviour, explains the fact that the main part of pelagic organisms form aggregations more or less structured. For a predator, living in schools, the concentration of its preys (or its food in a larger sense) plays a more important role than its average abundance, within certain limits, of course. In this matter, the fisherman is not very different from a « natural » predator since he seeks also for concentrations of schools.

But another consequence of that distribution concerns directly the scientific researcher : if he tries to collect the information according to a regular and systematic sampling, it is highly probable that he will miss the phenomenon he wants to study. Therefore it can be of a major interest to be able to « guide » the sampling pattern from direct observations of the aggregation phenomenon. In the aquatic environment, only acoustics enables such a remote observation. The tunas of the Equatorial Atlantic give us an example of its use, leading to elucidate the paradox of tuna concentrations in areas known as less productive.

FISHERY OF TUNAS IN EQUATORIAL ATLANTIC

Since about 15 years a seasonal fishery of tunas has been developed in a well-defined area of the equatorial Atlantic (Fig. 1), from 10° W to 20° W, between the equator and 5° N approximately (Fonteneau, 1994). The captures rapidly increased during the first years and then stabilized around 40 to 50,000 tons per year, with important inter-annual variation (Fig. 2). In fact, it concerns a multi-specific fishery with rather equivalent captures of skipjack *Katsuwonus pelamis* and yellowfin *Thunnus albacares*, with small quantities of bigeye *Thunnus obesus*). There is a clear seasonal influence upon captures : skipjacks compose the major part of the captures from November to January, then yellowfins from January to the end of March and bigeyes being scattered rather uniformly all along the fishing season (Fig. 3) which lasts about six months, from October to March.

THE PARADOX OF THE PRESENCE OF TUNAS

That area belongs to the equatorial current system. It takes advantage of a seasonal enrichment due to the development of an upwelling along the equator which lasts about 3 months during the boreal summer (from mid-June to about mid-September). During that period, the tuna fishery is inactive in the area, and apparently tunas are also in a very weak quantity. Therefore the fishery begins after that period of enrichment, with the delay of about 1 month after the end of upwelling.

Moreover, the friction between the opposite South and North equatorial currents produces a shearing wave which could lead to eddies and raising of water enriched with nutrients. That wave, particularly active in boreal summer when it can be seen on satellite pictures (Fig. 4), may continue during the following months to "fertilize" the area located North of the Equator (Morlière *et al.*, 1995).

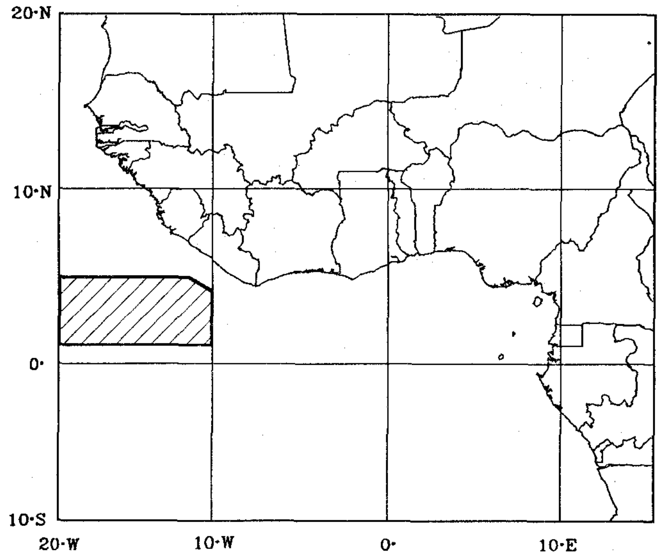

Figure 1 Location of the studied area (Fishing Area "Liberia").
Gambar 1 Lokasi penelitian (Daerah penangkapan Liberia).

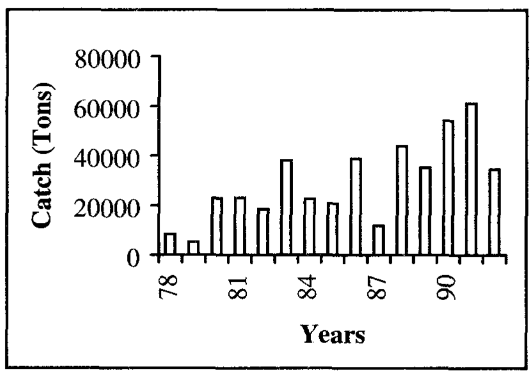

Figure 2 Annual total catches of tuna in the Liberia Area, 1978 to 1992.
Gambar 2 Hasil tangkapan tahunan ikan tuna di perairan Liberia pada tahun 1978 hingga 1992.

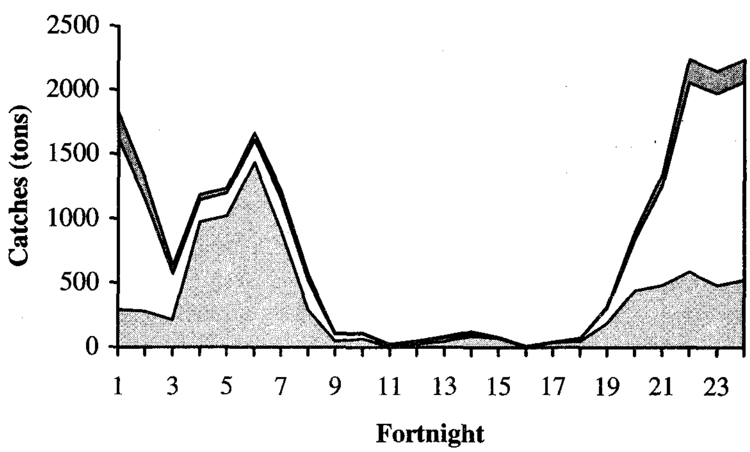

Figure 3 Average fortnightly catches of the 3 main species of tuna in the Liberia Area, during the same period.
Gambar 3 Rata-rata hasil tangkapan dua mingguan 3 jenis utama ikan tuna di perairan Liberia, pada kurun waktu yang sama.

Figure 4 **Satellite image showing a Long Wave north to the equator, underlined by a thermal front (Meteosat image, 07/07/94, UTIS, Dakar).**

Gambar 4 **Citra satelit memperlihatkan gelombang panjang utara ekuator dengan penekanan pada perbedaan garis suhu (Citra Meteosat, 07/07/94, UTIS, Dakar).**

Anyway, the epipelagic fauna has a very low abundance during the tunas fishery season, whereas tunas are "great eater". In fact, they have to constantly swim in order not to sink because they are lack of swimbladder (case of skipjacks), or they have one but not very developed (yellowfins), and they have anyhow negative buoyancy. Moreover, they swim rapidly, spending a lot of energy. On an average, a tuna consumes every day about 5% of his own weight (Olson and Boggs, 1986). It is generally accepted, and that has been confirmed by our own observations of stomach content, that tunas feed almost exclusively during day-time because they need to see their preys to catch them. The only important biomass of potential food is composed by mesopelagic organisms (mainly fish of the Myctophid families, Gonostomatids, etc., and Euphausiids). But those organisms, forming layers, perform dial vertical migrations from the surface during night-time to depths of 4 to 500 meters during day-time, as it has been observed in a close area (Marchal *et al.*, 1993) (Fig. 5). Here is one paradox of the feeding of tunas living in the high seas : the only abundant food seems to exist beyond their reach.

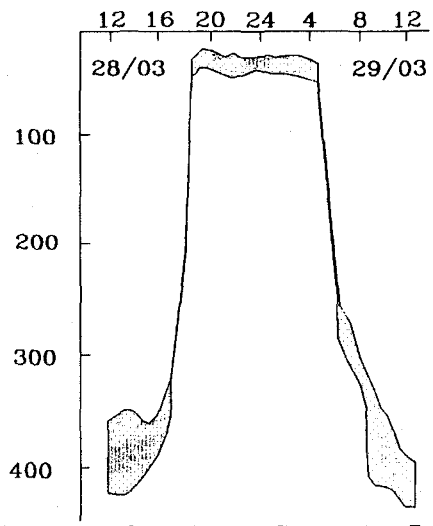

Figure 5 **Typical dial migration of the Sound Scattering Layer (SSL) as observed in the Equatorial Atlantic during 28-29 March 1976. Depth in meters on vertical scale, time in hours on the horizontal scale.**

Gambar 5 **Ruaya harian Lapisan Hamburan Suara (LHS) diamati pada perairan Atlantik Ekuator pada tanggal 28-29 Maret 1976. Kedalaman dalam meter dan waktu dalam jam.**

A study has been realized upon the diet of the tunas that are present in that area during the period of their concentration (Roger and Marchal, 1994) : the examination of the stomach content of the 2 major species caught during a research cruise performed in November 1992 (MICROTHON 03, R/V André Nizery) has shown that 73% of content volume was made up by a single species, *Vinciguerria nimbaria*, from the family of *Photichtyidae* (close to *Gonostomatidae*)[1]. This fish of small size, not exceeding 5 cm of length, is considered to belong to the mesopelagic fauna that perform dial migrations : actually, adults had rather never been caught during day-time within the surface layers of oceans (Blackburn, 1968). The fresh condition of *Vinciguerria*, found in the stomach of tunas caught during day-time, excludes a nocturnal feeding of tunas. We face then the following alternative : either the tunas were able to dive deeper than it was supposed and to seek for their preys at depths of 400 meters and so, in cold waters that do not fit their habitat, or the *Vinciguerria* could have stayed during day time within the surface layers, contrarily to previous observations. A bibliographical study of previous analysis of the stomach contents of open sea tropical tunas, has shown that, in fact, at least in the case of skipjacks, *Vinciguerria sp.* represented one of major constituents of their diet (Marchal and Lebourges, 1996).

During the same cruise, plenty of detections have been observed in certain areas of the prospected zone, particularly -- but not exclusively -- where tunas have been caught. Diurnal and nocturnal detections presented themselves in very different ways. Daily, they formed small schools, usually arranged in layers and, at 100%, constituted of adults *Vinciguerria nimbaria*, according to pelagic trawling (Fig. 6a). Nightly, the detection is more classical and appears as an almost continuous thin layer (10 to 15 meters approximately) situated rather at the same depth as the day-time schools, and containing large schools or swarms (Fig. 6c). Those swarms, sampled by pelagic trawling, were mainly composed of *V. nimbaria* : on an average 50% of captures, but certainly more into the swarm itself. According to temperature profiles carried out with a CTD probe, where those detections were present, the schools of Vinciguerria appear to be located essentially around the bottom of the thermocline (Fig. 6b).

However, previous observations made in the same zone, have shown that the schools of *Vinciguerria* were not exclusively seen at the level of thermocline, but were moving around within the surface layers during the day-time. It seems that, at the end of night, the *Vinciguerria* go up to the surface very rapidly towards the surface where they scatter, and then, at the very early morning, form schools which will go down towards the thermocline during the morning (Fig. 7); then, they stay there the rest of the time.

An observation of analogue behaviour has been done to a closely related species, *Maurolicus muelleri*, along the South African coasts. But unlike the *Vinciguerria*, they continue to go down in the morning towards the deeper part (Armstrong and Prosch, 1991).

In conclusion, those acoustic observations identified by trawlings, have clearly shown that the *Vinciguerria* schools could stay in the day-time at a depth accessible for tunas.

[1]The stomach content of tuna caught in the liberian area (november 1992) was represented at 73% by *Vinciguerria nimbaria*, 14% by other fishes, 11% by phronims, and 2% by cephalopods.

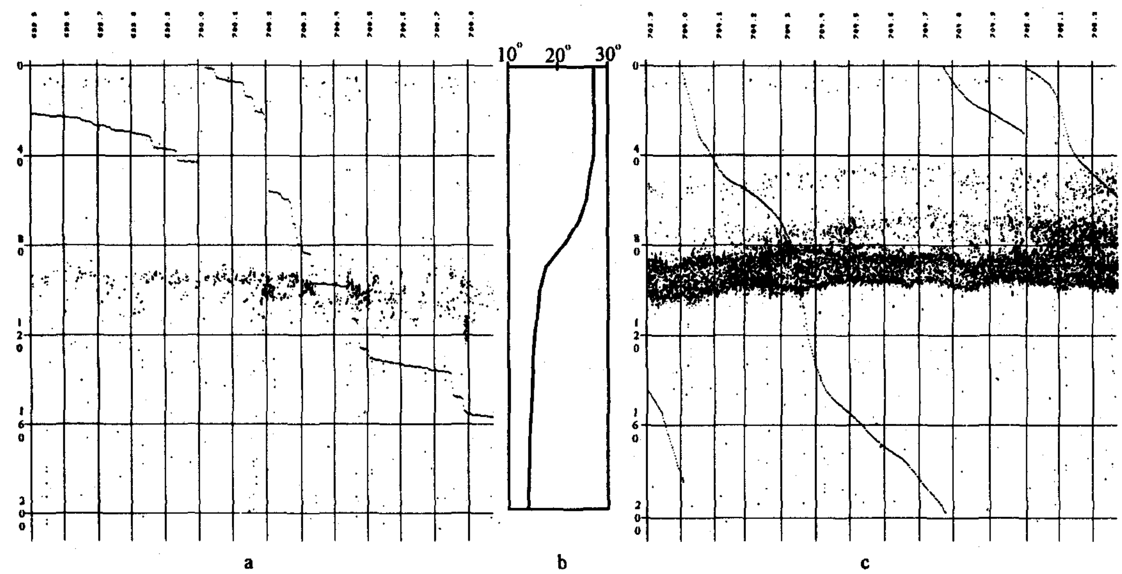

Figure 6 **Typical detection of *Vinciguerria nimbaria* and thermal structure : a/ daylight echogram showing small schools; b/ thermal profile, showing a well-marked thermocline between 60m and 90 m depth; c/ night echogram showing a scattering layer with swarms inside, at the bottom of the thermocline, about the same depth as during daytime.**

Gambar 6 **Keberadaan *Vinciguerria nimbaria* dan struktur suhu : a/ Echogram siang hari memperlihatkan kelompok-kelompok kecil ikan ; b/ penampang tegak suhu memperlihatkan lapisan termoklin pada kedalaman 60-90 m; c/ Echogram malam hari memperlihatkan adanya lapisan hamburan dengan pengelompokan didalamnya, dibawah lapisan termoklin pada kedalaman yang relatif sama pada siang hari.**

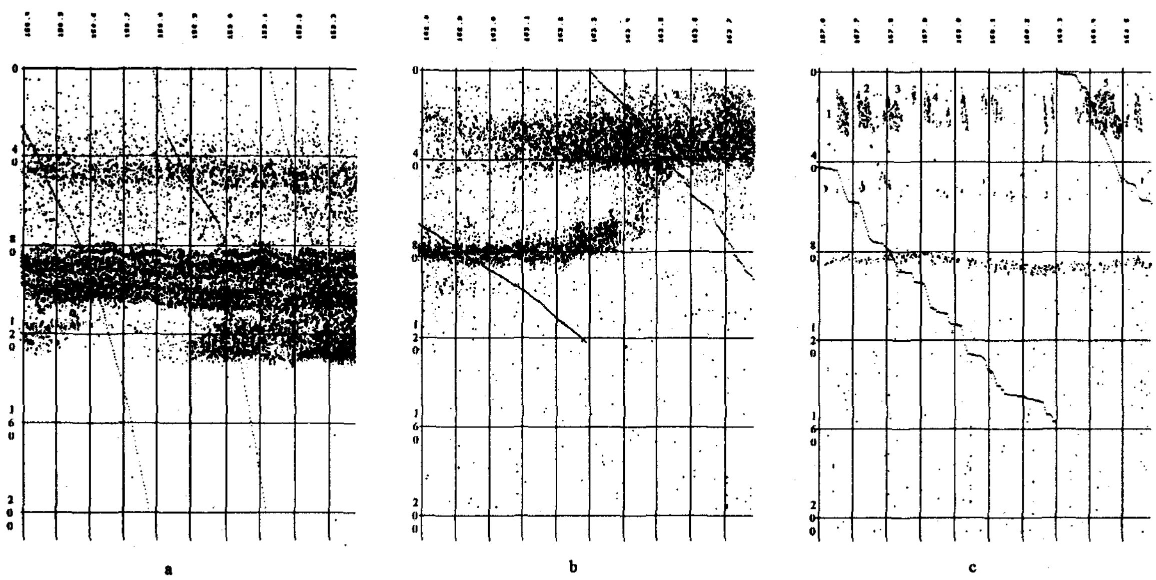

Figure 7 **Echograms showing the behaviour of *Vinciguerria* at the end of a night dark, dawn and early daylight).**

Gambar 7 **Echogram memperlihatkan perilaku *Vinciguerria* pada periode akhir malam hari menjelang pagi hari.**

In order to control more directly the behaviour of tunas and their capability of diving, 2 tunas have been marked acoustically during another cruise made in the same zone and at the same period, in November 1994 (MICROTHON 06). The mark consists of a small transmitter fixed on the fish's back and it can work for several days. It transmits, at regular intervals, the swimming depth of the fish : in addition, the orientation of the hydrophone, fixed on the ship or towed in a paravane, allows to determine approximately the direction of the fish compared to the ship. A skipjack and a yellowfin, both of about 50 cm of fork length (FL), were marked in the course of this experiment. Both of them did not go deeper than 80 meters, except a few very fast divings till 110 meters for the skipjack, and a little bit less for the yellowfin. The latter has shown a rather strange behaviour, going up and down regularly within the surface layer. Concerning the skipjack, it stayed much more stable and remained more or less within the range 50 to 70 meters depth during the 22 hours of its observation. A thermal profile shows that the thermocline was situated between 50 and 100 meters, with a strong gradient from 50 to 80 meters (Fig. 8).

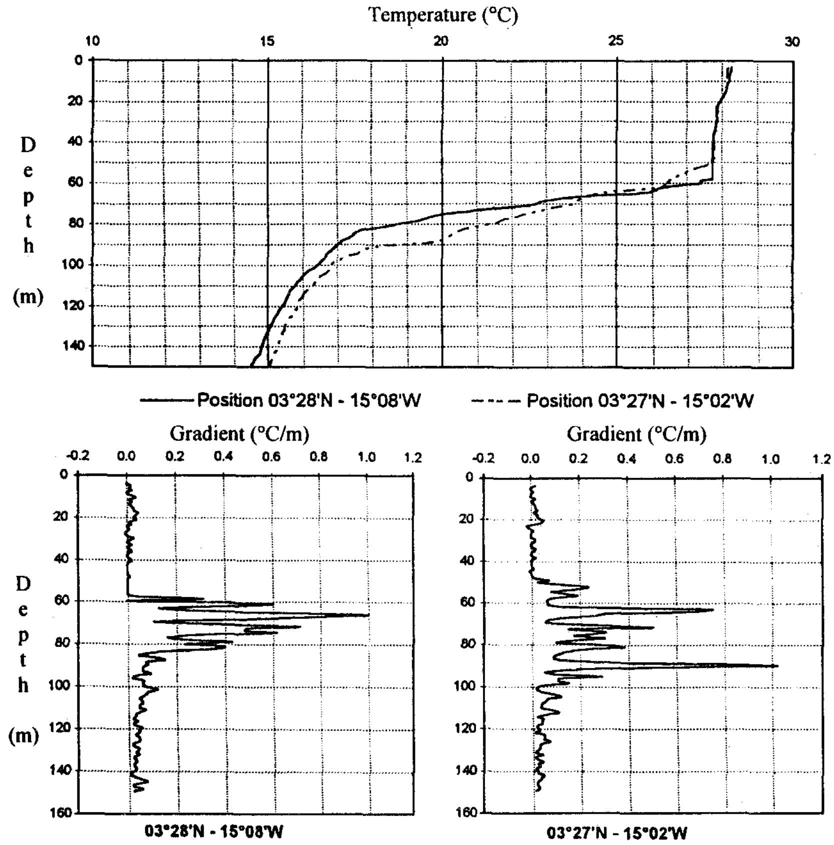

Figure 8 **Thermal profiles just before and after the acoustic tracking of the skipjack. Look at the very strong gradient between 60 and 80 m depth.**

Gambar 8 **Penampang tegak suhu sebelum dan sesudah jalur akustik tuna. Terlihat adanya gradien yang sangat nyata pada kedalaman 60-80 m.**

In the day-time, the skipjack was particularly stable and moving around between 60 and 70 meters, where the schools also present (Fig. 9). Other skipjacks caught in the same time than the marked fish, had their stomach full with *Vinciguerria*. It seemed then clearly that tunas present in that region, at least skipjacks and young yellowfins, stay in the supra-thermocline layer and by that way cannot reach the deep layers where the major part of the meso-pelagic organisms is located during day-time. But on the opposite, they feed actively on some meso-pelagic organisms which stay at day-time stay in the surface layer and particularly at the level of thermocline. Among those mesopelagic species behaving "abnormally" at least at certain periods, leaving their diurnal migrations, the fish Vinciguerria is largely in majority, but other species have shown the same behaviour and feed also tunas : notably the fish *Maurolicus muelleri*, a closely related species of *Vinciguerria*, and *Euphausia gibboides*.

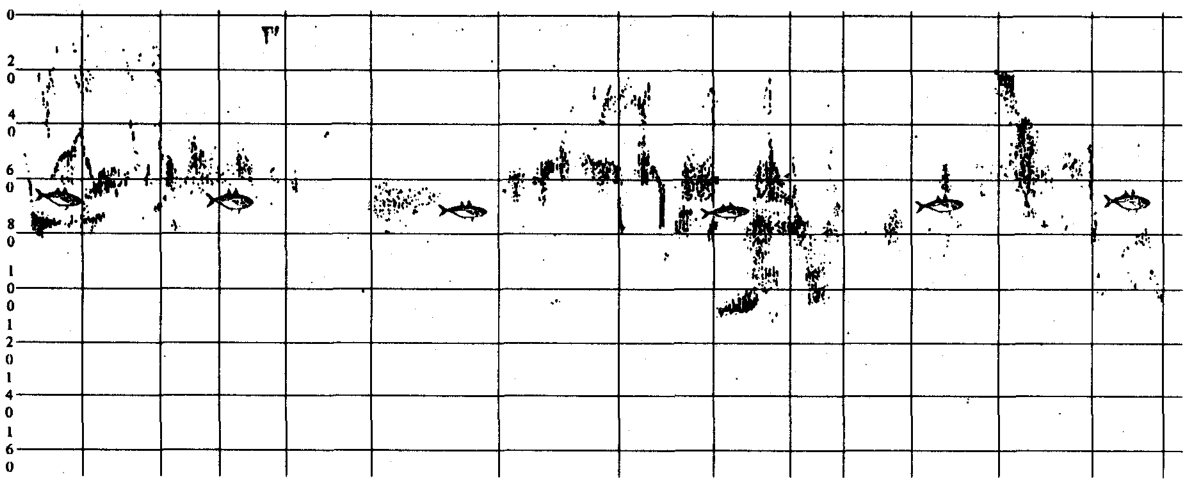

Figure 9 **Echogram showing the schools with the track of the skipjack superimposed on it. Time 8:30 to 9:00 a.m.**

Gambar 9 **Echogram memperlihatkan *superimpose* antara kelompok ikan dan jalur tuna. Waktu : 8:30 - 9:00 a.m.**

PACKING DENSITY OF SCHOOLS AND ITS IMPORTANCE FOR TUNAS

Acoustics can allow to evaluate the density of schools in number and weight, to estimate their volume and the biomass of fish that constitute them. For that purpose, we have to know the acoustic response of 1 fish, that is its Target Strength (TS), which depends of the fish size. There are several methods to measure it, one of the most pertinent being to measure the acoustic response of fishes kept alive in a cage or immobilized by thread. But those methods can not be applied to very small size fishes, fragile and moreover generally living rather deep. In this case, are arising problems related to the volume variation of the swimbladder. We have been able to realize a few TS measurements with a Dual-Beam echo-sounder that enables to calculate TS of single fish by comparing the echoes received on two beams presenting very different directivities.

The major problem with these *in situ* measurements is that we ignore the actual size of the fish being measured. However in the case of the *Vinciguerria*, there was a single mode in the size distribution, which can be accepted as the average size of the fishes. We could have then determined that the fishes of an average size of 47.5 mm of length of Standard Length (that is to say, 55.5 mm of Total Length) and a weight of 0.85 g presented an average TS of -59 dB (Fig. 10). That value is very close to another one calculated from an equation established for sprat, a small fish of very much like morphology, at the same frequency (120 kHz) and which is TS = -58,2 dB (Degnbol *et al.,* 1985).The other parameter that we need, in order to evaluate the average density of a school, is the average reverberation or volume scattering (Sv) expressed in dB per m^3. Average volume scattering for various types of schools is reported in Table 1, which contains also a few average geometric characteristics of those schools. The average Sv of schools that are supposed to be *Vinciguerria* has been found equal to -52,6 dB. The corresponding average packing density, d, is therefore calculated as follows :

$d = 10^{[(Sv-TS)/10]}$ =3.6 fishes per m^3,that is in weight : 0,85 g. x 3,06 g/m^3

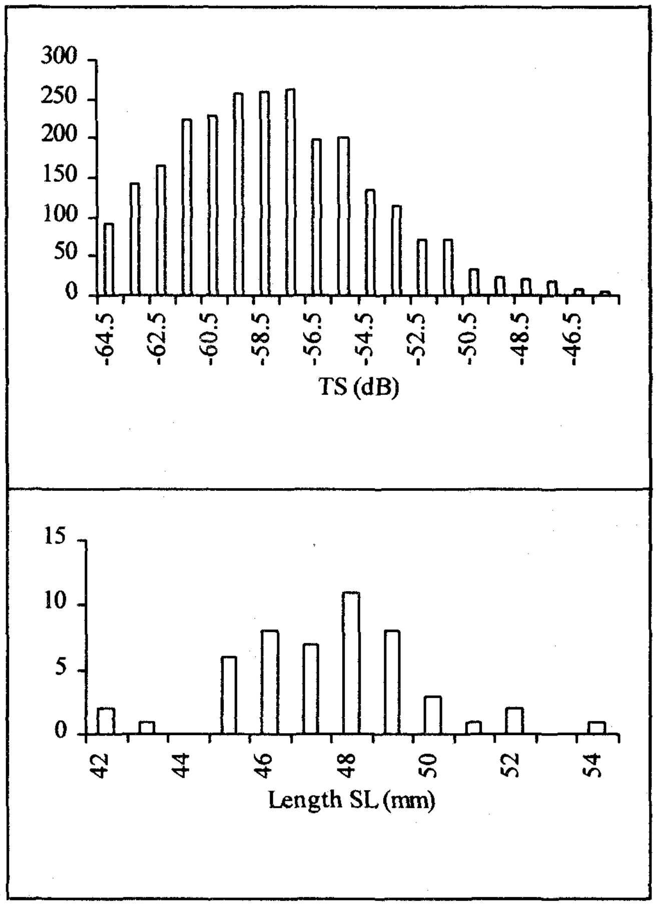

Figure 10 Up : Target Strength (TS) histogram of assumed *Vinciguerria* from Dual Beam measurements. Down : size histogram of *Vinciguerria* caught in the same area.

Gambar 10 Atas : histogram besar ukuran (*Target Strength*) dari *Vinciguerria* dari pengukuran bim ganda. Bawah : histogram ukuran hasil tangkapan *Vinciguerria* pada daerah yang sama.

Table 1 Mean characteristics of different types of aggregations.

Tabel 1 Rata-rata karakteristik beberapa tipe kelompok ikan.

Position	Type	D/N	Rv+ (dB)	Hmax (m)	Lmax (m)	Nb
Thermocline	Dense	N	-53.5	18 (18)	1800 (Est)	93
	Diffuse	J	-57.4	8 (4)	49 (24)	28
	Dense	J	-52.6	8 (5)	121 (209)	84
Surface layer	Diffuse	J	-58.7	10 (9)	66 (90)	56
	Dense	J	-52.4	23 (12)	128 (88)	12
	Very dense	J	-49.2	8 (1)	76 (14)	3

Rv+ : volume backscattering strength; Hmax : maximum height; Lmax : maximum length.
Nb : number of aggregations taken into account; D/N : day/night; Est : estimated value; standard deviations in brackets.
(+ Rv : volume backscattering strength; H max : tinggi maksimum; L Max : panjang maksimum; Nb : jumlah kelompok ikan terhitung; D/N : rasio siang malam; Est : nilai dugaan; simpangan baku di dalam kurung.)

That density may appear weak : it is true in comparison with schools of pelagic fishes (anchovy for example). However, that density corresponds, in terms of quantity, with Myctophids aggregations as they were observed during undersea diving. Thus, it has been estimated that the distance between 2 fishes, in such aggregations, was within the range from 2 m to 15 meters, which represents a density of 0.18, and therefore a number of 418 fishes per m^3 (Auster *et al.*, 1992). Another observation deriving from diving, mentioned 2.5 fishes per m^3 for a species of Myctophids within an aggregation, against 0.03 fish per m^3 beyond the aggregation.

The average dimensions of the « dense » schools in the thermocline attributed to Vinciguerria, are 120 metres long and 8.3 metres high. If we assume that these schools have a cylindrical form, we obtain an average volume of 93,870 m^3. This corresponds to an average school weight of 287,244 g or 287 kg. Knowing that the average weight of a 50 cm long tuna is about 2.5 kg and that, each day it eats 5% of its weight (see above), that is to say 125 g, such a schools, theoretically, can be sufficient to feed about 2,300 tunas during 1 day.

CONCLUSION

The main objective of this paper was to show how acoustic could be a precious tool to study predator-prey relationships because it allows to know the spatial structuration of preys and to study the behaviour of predators with regard to that structuration. But acoustics allows also to estimate the relationships between predator and prey abundances, at various spatial scales. Lastly, this method enables us to discover phenomena which cannot be seen through other ways, such as the « unexpected » behaviour of *Vinciguerria*, which certainly brings a major contribution to the concentration of tunas in that region.

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DISCUSSION

(Chairman Dr. FATUCHRI)

Dr. NURZALI

Q : - If we know the size of the prey stock, can we deduce the size of the predators ?

A : - Tuna is a migrating fish and in this area we found only a part of the stock. Tuna spend one part of their life in this region. Indeed, it is possible to predict the variations of the tuna stocks, from the variations of the prey stock (*Vinciguerria*), if we know the relationship between preys and predators.

Dr. NAINGGOLAN

Q : - My question is about the calibration of the equipment. Is it necessary to measure the beam pattern of the Dual-Beam transducer before Target Strength measurement or you just accept and apply the parameters given by the manufacturer ?

A : - It is always possible to do such calibration in the field. Actually, it needs work and time to perform this checking and it requires a special place with ideal condition to measure. The Project team used the manufacturer's data for the transducer's beam pattern. According to the directivity, I do not think that directivity changes with the time. The team regularly made calibration on the Source Level and the Sensitivity of the transducer and the equipment.

Dr. PASARIBU

Q : - Based on your own experience, which system do you prefer to use ? The Dual-Beam system or the Split Beam system ?

A : - Ten years ago, I would have said that Dual-Beam was better as the technological result of long experience. At the very beginning, the Split Beam encountered many problems. The Split Beam is nowadays better because this technique is less affected by the noise. Both systems have been improved. They can provide the possibility to track the fish. You can get, in this way, more precise Target Strength measurements.

Q : - In term of equipment, we must consider the problem of the fish orientation and localization in the beam. Can we be sure of the localization of the fish, using the Dual-Beam system, for example ? I feel that it is still questionable. For the Split Beam, it is said that the process based on the phase difference principle gives the orientation of the fish within the acoustic beam. There is not equivalent ability in the Dual-Beam system.

A : - The Split Beam allows you to know the true geographical position of the fish. This position is referred to X and Y coordinates related to the axis of the transducer and a third coordinate that we can call Z related to the transducer's face, that gives you complete positioning of the fish in the space. In the case of the Dual-Beam, the difference between the responses of the narrow and wide beams is simply used for the correction of the directivity. This technique does not localize the target in a coordinate system. The single information you can get, besides the directivity correction, is the depth of the target which, therefore, can be anywhere on a circle without any more detail to specify where its location is.

For precise measurement, it is interesting to track the fish. You can see if the fish is moving by following the Ts variations. In this case, nevertheless, neither the Dual-Beam, nor the Split Beam will give you the true TS value because both do not take into consideration the fish's attitude and its proper directivity neither. I will recommend to use the Split Beam for accurate measurements. About the dynamics of -160 dB praised by the manufacturer of the Split Beam, we can say that it is a nonsense and just a commercial promotion. Both methods give bias. In congress of Acoustics, we talk about these biases. It remains difficult for these systems to distinguish between fishes at the same depth.

As you can see in many examples, we often meet, at sea, very wide distribution that limits the use of the Dual-Beam and the Split Beam systems. You must be careful when using direct measurement with a very nice output supplied which gives you an average Target Strength or Backscattering Cross Section. Very often, the distribution is not very accurate; it is therefore better to extract the modal class, if possible and certainly more realistic than the average value.

DETECTION OF FISH STOCK ABUNDANCE AND DISTRIBUTION USING SATELLITE REMOTE SENSING AND HYDROACOUSTIC TECHNIQUES

V. SIREGAR, B. PASARIBU

ABSTRACT

The assessment method of fish stock abundance and distribution by satellite remote sensing and acoustic techniques have been progressively improved. However, regarding their limits, each method has disadvantages which influence the assessment accuracy. This paper is intended to promote an idea to use those methods collectively, which may contribute to the increasing of accuracy, the rapidity of the fish stock abundance assessment and its distribution within large area coverage.

KEYWORDS : acoustics, remote sensing, method, assessment, abundance.

ABSTRAK

Metode pengkajian kelimpahan ikan dan penyebarannya melalui teknik-teknik penginderaan jauh dan hydroakustik semakin memperlihatkan perkembangannya. Namun demikian keterbatasan masing-masing metoda tersebut dapat mempengaruhi tingkat akurasi dalam pengkajiannya. Tulisan ini menyampaikan pandangan tentang penggunaan kedua metode tersebut secara bersamaan yang diharapkan dapat meningkatkan akurasi dan kecepatan pengkajian kelimpahan sediaan ikan serta penyebarannya pada wilayah peliputan yang luas.

KATA KUNCI : akustik, inderaja, metode, pengkajian sediaan ikan.

The exploitation of living marine resources without considering the level of exploitation will result in degradation of the resources, since they are potentially exhaustible. To avoid harmful effects on these resources, the knowledge about fish stock abundance and its distribution is indispensable. The distribution and abundance of fish are directly related to the features of the oceanic environment, such as temperature, phytoplankton, salinity and water mass movement, etc.

During the last 2 decades, the methods of fish stock assessment and distribution have been significantly improved. The remote sensing methods have gained preference over the conventional methods such as trawl catch method and biostatistic method (Stepnowski, 1994). The conventional methods, beside their advantages, have, at least, 3 limitations, namely : - long time data acquisition and result, high costs, and limited capabilities of automatization. Acoustic remote sensing techniques have been used for many years using pulse of sound to penetrate the sea and view the sea bottom, or to observe suspended sediment or else biological activity in the deep scattering layer. Recently, those techniques have been developed to detect the thermocline structure of the ocean (Robinson, 1985). The acoustical method, which is one form of remote sensing compared to the conventional methods, has some important advantages such as : relatively large area coverage, relatively high accuracy and reliability, relatively rapid data collection and data processing, and flexibility with a high degree of automatization. The satellite remote sensing method has the advantages, namely : rapid large area coverage (synoptic view), long term monitoring and frequent coverage. Beside these advantages, satellite remote sensing method has disadvantages such as : inaccuracy caused by limitation in resolution and calibration necessity.

Considering the disadvantages of those methods, when they are used partially to assess fish stock abundance and distribution, the ensuing results are not fully satisfied. This paper deals with the idea to use together fully the satellite remote sensing and acoustical techniques, after considering their advantages and disadvantages. This integrated method may contribute to the increasing of the accuracy and rapidity of fish stock assessment and fish distribution within large area coverage.

SATELLITE REMOTE SENSING

The history of remote sensing is considerably older. The term of remote sensing was coined by geographers, at the US Office of Naval Research in the 1960's. Remote sensing may be taken to mean the observation or the acquisition of information about a target or an event, on the basis of measurement taken by a device, at some distance from it (Cracknell and Hayes, 1991). If remote sensing is regarded as the acquisition of information about an object without physical contact with it, almost any use of photography, taken by airborne, in a scientific or technical context, may be thought of as an example of the use of remote sensing. However, remote sensing is often regarded as synonymous with the use of satellite.

It is noted that primarily some satellites were developed for land based remote sensing. But in their implementation, they have been also used for oceanographical purposes. The US satellite environment program began in April 1960, with the launch of the first satellite, in its TIROS (Television and InfraRed Observation Satellite) series. An enormous number of other satellites has been launched since then, for environmental remote sensing work. Remote sensing, as a qualitative source of information, offers a unique contribution, such as : a global view, long term monitoring, and spatially detailed synoptic view.

Remote sensing observation of the ocean can provide a significant part of the information needed to assess the living marine resources. In this context, the information means the environmental parameters that affect the recruitment, distribution, abundance and availability of fishery resources. The environmental parameters, commonly measured by the satellite remote sensing sensors, are : concentration of dissolved and suspended matter, concentration of phytoplankton and sea surface temperature, using colour and thermal infrared sensors. The basic sensor is a radiometer which measures the electromagnetic energy reaching it from a given small beam in direction. Radiometers are used to measure in the visible, infrared, thermal infrared, and microwave part of the spectrum (Fig. 1).

In the visible, the interpretation is analog with the way we use our eyes to distinguish bright and dull surfaces, where intensity and color are very important factors. While, in the infrared and microwave parts of the spectrum, the interpretation of radiometric measurement depends on whether the energy is emitted by the surface itself, or merely reflected as in the case for visible spectrum.

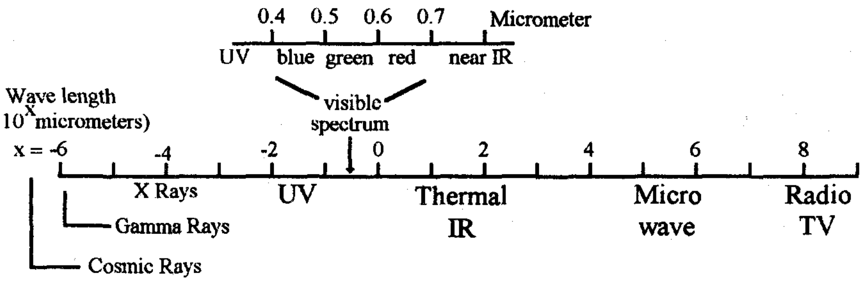

Figure 1 The Electromagnetic Spectrum.
Gambar 1 Spektrum elektromagnetik.

The satellite remote sensing sensors usually used to measure those parameters are namely :

- CZCS (1978 - 1986) - Coastal Zone Colour Scanner (NIMBUS 7)
- AVHRR (1978 -) - Advanced Very High Resolution Radiometer (NOAA)
- TM (1982 -) - Thematic Mapper (LANDSAT)
- VISSR (1978 -) - Visible Infrared Spin Scanner Radiometer (METEOSAT)
- OC (1987 -) - Ocean Colour (MOS)

In the next future, many satellite sensors will be launched such SeaWifs (NASA), Octs (NASDA) and Polder (CNES). All the sensors will include more channels than that already existed. The particular importances of the coming sensors are an increased radiometric sensitivity, and a well-adapted dynamic range in each channel, that allows the sensor to be operated full time.

Even though there are conflicting point of view on the importance of satellite remote sensing for fisheries (Stuardo, 1993), the remote sensing techniques can be utilized directly, indirectly, or as general aids in fisheries oceanography for the detection and assessment of fishery resources (Butler *et al.*, 1988). The direct detection of fish stock is the most obvious goal in fisheries remote sensing work, but, in fact, it is the most difficult to achieve. Indirect method, however, seems to offer better perspectives to detect fish stocks and their distribution, because it is possible to correlate the detection with, at least, the common parameters measured from satellite sensors, such as chlorophyll concentration and sea surface temperature.

Techniques have been developed to quantify biological productivity on the basis of chlorophyll concentration which is converted from the radiance value, using a pigment algorithm or band ratio. Water temperature, which is also converted from the radiance value, is another important factor in determining the species distribution. Thus, the result of ocean colour and thermal sensors measurement can be used to produce maps of the primary productivity and distribution of surface temperature of the ocean. With the knowledge of the area of chlorophyll occurrences and sea surface temperature, particularly in thermal fronts derived from satellite remote sensing, it is possible to assess the fish stock abundance and distribution of fish (Cram, 1979; Laurs, 1984).

The principle of hydroacoustic technique is the use of sound for detection or searching the underwater objects. Pulses of sound are transmitted away from a transducer and propagate through the water column. The pulses encounter various targets, e.g. fish, plankton or sea bed, and these targets reflect and return a part of the acoustic energy toward the transducer. This reflected sound (echo), received by the transducer, is then converted into electrical energy as the received signal. Then, this signal is amplified and displayed on the echogram. The hydroacoustic system consists of, at least, 3 components, namely :

- the transducer, usually mounted in towed body,
- the echo-sounder, for signal transmission and reception of echoes,
- the signal processing equipment for real time and/or post processing data.

In Acoustic survey, echo signals, acquired from successive transmissions, are usually recorded on digital tape and simultaneously displayed on echograms. The processing of the echo signal consists in integrating all the echo signals. In addition, in situ target strength estimation may be performed to convert echo integrator reading into absolute fish density estimates.

The principle, which governs the generation of integrator-fish densities estimates, is that the energy of echo signal from fish is proportional to the fish density. This technique, due to its versatility, accuracy and reliability, has become a routine or a standard method (Stepnowski, 1994). In complementary surveying by sonar, fish schools may be counted and mapped. Echo-sounding can be used as a sampling technique for fish population.

The Target Strength of fish is an important parameter, for 2 reasons:

- as a part of the scaling factor, for both echo-counting and echo-integration. The other factor to define the scaling factor is the acoustic apparatus coefficient,
- as an indicator of fish size.

Therefore, the Target Strength measurement of fish is very important, especially when defining the fish abundance and its distribution, in a certain sea water area.

The accuracy of fish abundance estimates much depends on the correct value of fish Target Strength measurement. In situ techniques include indirect and direct fish Target Strength measurements. Since the location of a fish in the acoustic beam of a single beam transducer is not known directly, Target Strength information must be extracted statistically, or indirectly, which is consuming time and the resulted values are not properly correct. Direct techniques involve multiple beam transducers that can locate the fish in the beam and correct the received signal from the directivity effect. Therefore, the fish orientation in the beam angle, which is unknown when using a single beam transducer, can be solved by using multi-beam system. The most widely used direct techniques are dual-beam acoustic system and split beam acoustic system. The dual-beam technique measures the echoes from a fish on a narrow beam and a wide beam of a transducer. Since the directivity (sensitivity) of the narrow transducer changes more rapidly with the angle than the wide beam, this angle can be determined by the ratio of the echo strength received on 2 channels (1 for each beam). As it is the case with echo-counting, care must be taken to differentiate individual fish targets from multiple fish targets and noise.

The split beam method employs the phase difference measurement for determining the target angular location, which allows removal of beam pattern effect factor. It utilizes a four-quadrant transducer, and during the transmitting mode, all the four quadrants are driven simultaneously with identical amplitude and phase. In the receiving mode, after TVG (Time Varied Gain) adjustment of echo amplitudes received by each individual quadrant, the difference in the path lengths, between each quadrant, from a particular target, can be determined. Therefore, the fish location in the beam angle can be known.

The acoustic survey, in a certain seawater, is done by designing cruise track, covering all the area. The transects may be parallel to one another or they may zigzag in a triangular pattern. The best design of cruise track depends upon what is known about the distribution and behaviour of the target species, and the kind of information which is required for the survey.

COMBINATION OF SATELLITE REMOTE SENSING AND ACOUSTIC TECHNIQUES

As we already know, information gathered from satellite remote sensing can not be as accurate and relevant as that collected from vessels at the sea. The prime reason is caused by the electromagnetic radiations used by the sensor which barely penetrate the sea surface. Although a part from visible wave length can penetrate more than 20 m, it is true that satellites observe only the surface of the sea, and are limited to a two-dimensional view. In reality, the vertical structure of the sea is very important, because it is relevant with current velocities, salinity, temperature, distribution of primary productivity or fish population.

Furthermore, the characteristics of the satellite orbit limit its time sampling capabilities, at a given location, to discrete overpasses once or twice a day, or every several days, except in the case of the geostationary satellites. Comparing to continuously sampling or integrating sensor mounted on a vessel (acoustic device) or buoy, the satellite's sensors appear less effective (Fig. 2). This condition does not occur in the case of microwave sensors that provide all weather sensing of surface phenomena, such as height of sea wave or roughness of sea surface, which do not have a depth dependence at all. Satellite may be used to sample only a certain depth range where occur exchanges of energy and matter between the ocean and the atmosphere.

The advantages of satellite data are its two-dimensional synoptic view, its high spatial resolution, and its ability to provide a low frequency time series over long term periods, even at isolated oceanic location. By other means (ship or buoy), the synoptic view is impossible and the long term period sampling would be very expensive. It would require many ships to obtain a truly synoptic survey of a large region, and even then, the spatial sampling would be very coarse.

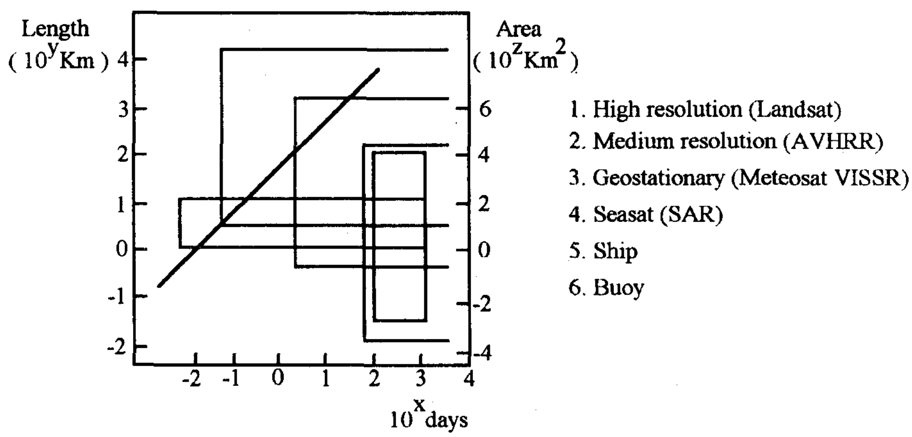

Figure 2 Space - Time sampling characteristics of Sensors.
Gambar 2 Karakteristik ruang-waktu menurut sensor.

The colour and thermal infrared scanning sensors have great potential values, even if the records are only the occasional cloud-free image at irregular interval, for they supply a synoptic view of the horizontal spatial structure. The accuracy of remote sensing measurement can be improved, by calibrating the data with the true sea data, and acoustic data may be considered as true sea data (Fig. 3).

For calibration purpose, there are 2 important problems encountered in gathering true sea data; they are namely :

- how to use the true sea data, which happened to be collected within the field of view of the satellite sensor, at the time satellite overpassed,

- how to obtain, as broad as possible, data for calibration. It is desirable to obtain true sea data over a wide range of possible values, corresponding to a wide range of satellite data values. This requires true sea data to be obtained at many different locations within the image field, simultaneously with the satellite passover.

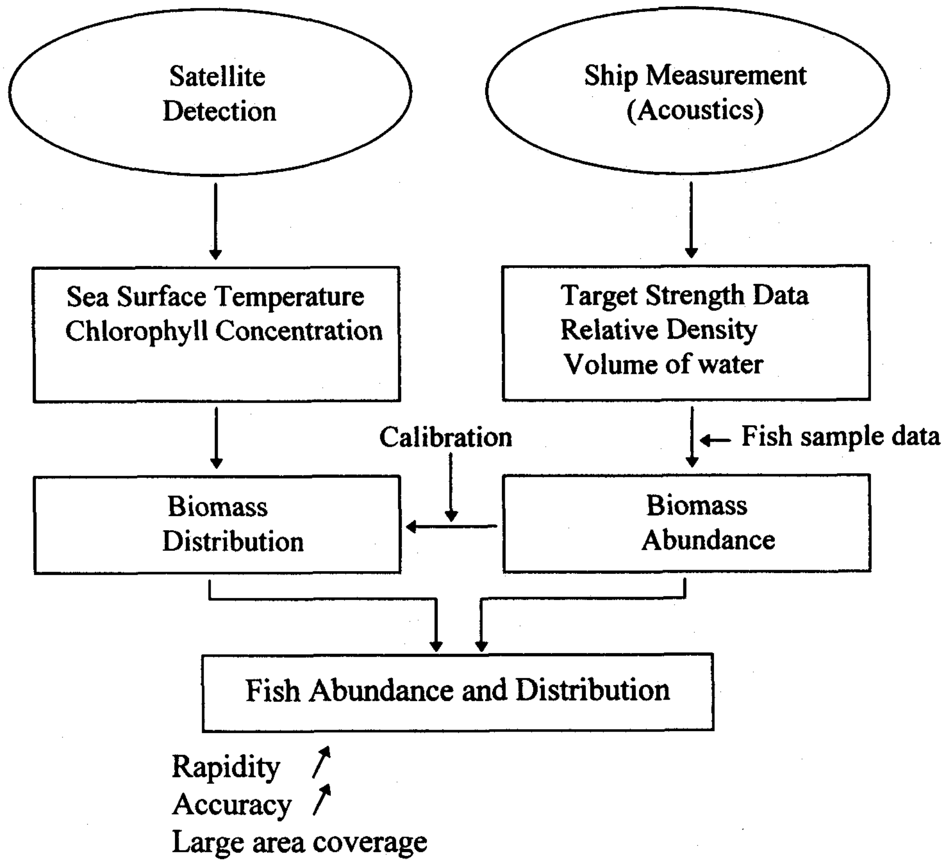

Figure 3 **Flow diagram of model.**
Gambar 3 **Model diagram alir.**

In order to attempt to solve the problems of calibration, an approach can be suggested as follows :

- the instruments (including acoustic device) would be adjusted to measure particular parameters of fish stock abundance relevant to the task of satellite data calibration;
- a single vessel steers a suitable course across strong gradients of parameters being calibrated, making continuous measurements as the ship is underway.

These solutions are not so easy. It is likely that the parameters to be evaluated will not be measured in the way chosen for true sea measurement. Besides, the preparation of the cruise may require several previous images of an area to be studied, in order to use them as a guidance on typical spatial distribution of parameters. The next step is to design an efficient strategy for gaining broad range parameter values from a limited number of samples, or from a single transect of continuous measurement.

The conventional methods for the assessment of fish stock abundance and distribution, such as trawler swept area method, surplus production method, biostatistic method, etc, can also be used as information sources about distribution and behaviour of the target species. Therefore, a judgment on fish abundance estimates, in a certain seawater area, can be done more accurately.

CONCLUSION

Using satellite remote sensing and acoustic techniques, it appears possible to detect fish stock abundance and distribution with the level of accuracy comparable to that of the true sea data, within large area coverage and relatively rapidly. Acoustic data, which are received from ship measurement, would be considered as true sea data for remote sensing data. The critical point in this method is the sampling strategy. It is hoped to obtain true sea data over a wide range of possible values, corresponding to a wide range of satellite data values.

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DISCUSSION

(Chairman Dr. MARCHAL)

Dr. NURZALI

Q : - How deep can we go in detection ? What about the resolution of the details in satellite imagery ? What about the cloud cover in Indonesia ?

A : - We use wavelengths from the ultra-violet to the infra-red. The spectrum in remote sensing is from the visible to the microwave. The visible has the capability to ponderate the water column to a certain depth according to its turbidity or the sea state. The thermal infra-red studies the surface until 1 mm of thickness. These microwaves cannot penetrate and backscatter any object on the surface. However, it is possible to use the visible data in oceanography although the penetration is limited. We can have information until 20 m depth. As we know, the inter-action of the sea and the atmosphere occurs within this depth layer. The coverage of the satellite limits also the resolution. For example, LANDSAT has a resolution limited at 30 m and SPOT has a resolution limited at 20 m. As I said before, the information collected by the sensors is the average of the whole area. We have still problems with the cloud cover, principally for studying the sea water temperature and the concentration of chlorophyll or sediment. Weather condition remains an important factor that affects the visible and thermal sensors in certain part of the region. For oceanographic observations such as the force of the wind or the height of the waves, we can use the microwave channels.

Ms. INDIHARTI comments : "We will try soon to make FST maps or use ERS-1 satellite to solve the problem of the cloud cover. The data are radar data, but it is possible to measure the FST. The sensitivity for temperature measurement is higher : 0.2 °C, instead of 0.5 °C with the NOAA system. For marine application, we will need *in situ* measurements in the field in order to validate our results."

DISCUSSION AND PROSPECTS

During this second session, the communications have concerned the new application fields of Acoustics. Recent technologies, involving multi-beam or multi-frequency sounders developed for three dimensional spatial analyses, have not been approached. Their analysis means, easy to use for common purpose, are still lacking.

Generally, Acoustics is used for biomass evaluation. All along this session, the different authors have presented other approaches that, thanks to this technique, allow to define a school of fish and to analyze the prey-predator and school-environment relationships.

The acoustic tool is the only one able to give a three-dimensional representation of schooling. It allows to study the school structure and its behaviour. In the case of the pelagic fish, the study of this organization and its dynamics is essential because the most important part of the fishing is effectuated on schools.

Thanks to its high sampling performances, the acoustic techniques allow to understand phenomena that seem to be contradictory. The approach of the relationship between prey and predator, this latter being tuna, is original in many ways. It proposes an explanation of the tuna concentrating in area seemingly poor. The persistence of the preys, at day, in the subsurface layers of the Atlantic Ocean, at the Equator, has been proved; this is an atypical situation. A sampling by means of common gears (midwater trawl, etc.) would have never allowed to know the richness and the bathymetric localization of these preys because of their overscattering. Besides, the use of "pingers" (acoustic tags) permit to find and track the predators'move during their daily breeding phase. All these observations are helpful to validate the given interpretation of events encountered.

The schools' "signatures" and their bathymetric localizations regarding to the environment have been used to define the proportion of species during assessment campaign in the temperate Atlantic. Behaviour changes have been observed among multispecific populations, regarding to their mixing. The results have been validated only thanks to a rigorous identification sampling. A narrow relationship appears between annual trends of abundance index obtained by acoustic means, egg counting and the catch levels. Meanwhile, this result has needed a long series of surveys difficult to sustain in tropical areas.

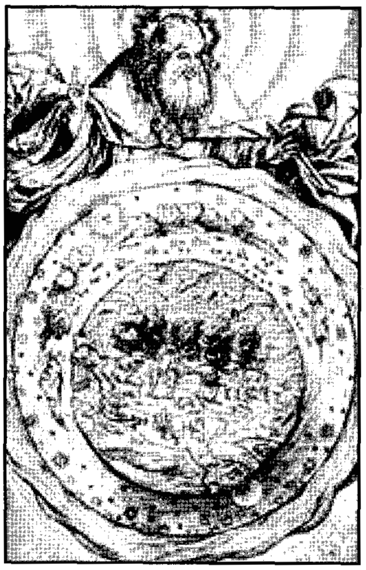
Dynamics analysis of schools leads to reconsider the relationship between preys and predators from a different point of view : the assessment validity. Nowadays, one admits that the most important part of errors or biases that limit the viability of the acoustic evaluations, is linked with a lack of knowledge on prey behaviour (besides the problem of detected species identification). This finding must lead to deeper research in this direction, by associating the analysis of the reaction of the fish in front of its main predator, Humans, and his dangerous adaptation abilities. The fishing impact or predation on the stock and the reaction of this stock facing observer can be examined in order to evaluate the assessment reliability. Recent observations tend to show that fish, particularly in schools, escapes from vessel getting closer. The main source of error seems to be this avoidance. The clearer and shallower waters are, the more important this avoidance is; the more noisy the ship sails either.

To conclude, if biomass evaluation is indispensable, it is as important to measure it without any considerable bias. The statistic error on evaluation, more or less important, does not take into account this avoidance. This error is found within the whole data probably biased in the way. About the Java Sea, new observations are necessary to confirm the previous results.

Part 3

Round Table

Conclusion and Lists



ACOUSTIC PERSPECTIVES IN INDONESIA MARINE WATERS[1]

This round table has been divided in 4 four parts, **the spatial scales**. These four spatial scales were :

- JAVA SEA.
- CORRELATED SYSTEMS with the Java Sea (system near or linked with Java Sea, for ecological and/or exploitation reasons).
- E E Z
- REGION and the role of Indonesia in South-East Asia.

JAVA SEA

Environment

It has been recalled that the study of productivity in Java Sea was very useful; the first suggestion was that this study might be achieved with a multidisciplinary approach on temperature, salinity, chemicals, chlorophyll, silicate and by means of acoustics, the evaluation of plankton biomass. It has been recommended to make an inventory list of what is already known and a list of what direction to go.

The second suggestion was to study pollution : heavy metals, industrial activities such as, in Natuna area, the oil pollution from the drilling plants. The meteorological parameters area also required surveys of rainfalls and the input of fresh water (precipitation and flood) which are the main constraint for salinity, enrichment that remains hard to assess (eutrophic and oligotrophic conditions) and pollution.

Following these suggestions, it has been proposed the installation of coastal station for observations in order to determine, for example, the movements of the waters (the increase of the number of laboratories has been planned). These installations seem to be very cheap and easy to manage. The experience of Orstom long term studies in Africa has been recalled.

The use of automatic observation systems like in Vietnam, might be too expensive. These systems collect parameters such as : temperature, salinity, pH, Oxygen. The system TOPEX-POSEIDON has been evoked as a means to survey the sea altitude and a mapping of water circulation. Telemetry systems for the fish behaviour could be taken into consideration.

The use of commercial ships for sampling can be conceived; by means of XBT measurements or taking samples of water, on their way.

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[1] [1]Note : continental waters could be included in this debate; for example; in JATILUHUR, acoustics could be useful to study the prey-predator relationship, from a scientific point a view.

Distribution, acoustic parameters and Target Strength

The need of TS data was clearly reminded as a tool for biomass evaluation and also for the ecological aspects that can be issued from these results.

The lack of data on juveniles and larvae could be overcome with surveys on Bagan (anchovies) which are fishing platforms using square fishing net. The surveys in the Bay of Semarang, the Barito basin, the shallow waters of Sumatra, the eastern part of the shelf of Java could supply deeper information on the coastal community (referred as the strata C in the last workshop). For that, some new equipment sets have been cited, such as : the BioSonics DT 6000 (35,000 US$) and the Simrad EY 500 (80,000 US$). Both portable echo-sounders perfectly fit for the sounding of coastal brackish systems with shallow waters.

Coming back to the distribution, in its general sense, it has been remarked that the first priority is to study in deep all the data, before conceiving any new survey strategy.

Acoustic and Management

Deeper studies on light attraction related to catch efficiency are necessary. Fish attraction must be considered under different aspects such as the vessel effect and the light power used (maybe the 20 kW total power is too much, hypothesis of a sill). Other techniques studies could be achieved deeper : underwater lamps (which seem to lose less energy for attraction but difficult to use for waterproofing reason) and also the strategy of the fishing vessels. Are they too many ? Are they too close to each other ? The study of techniques' efficiency and fishermen's behaviour will help us to define the wished number of boats.

The monitoring of the biomass was the big point of the discussion. Some of the audience did not agree with the necessity of such watch, because it seemed for them useless to trend to have biomass assessment, so unpredictable before understanding how the system works. The great majority claimed that, in any case, in order to understand the system and to manage any biomass, it was indispensable to monitor the area. Fishes are not only on the fishing grounds but also outside. That was the main motive expressed. Eventual collapses of fisheries are not predicted because there are two safeguards : the first is that we face multispecies fisheries (of juveniles' stocks, the adults are outside the Java Sea) and the second is that light fishing techniques allow generally, only one catch per day, restricting the taking.

Following these remarks, it has been suggested to investigate the stomach content of fish, mainly the plankton composition to understand the fish migration.

Finally, the monitoring has been pointed out as a necessity because many years of collecting data are needed to obtain a good tool in acoustics. Moreover, based on such observations, one can conceive the possibility to delimit zones for the conservation of fish, principally juveniles, to care the first year spawning.

CORRELATED SYSTEM with the Java Sea (system near or linked with the Java Sea, for ecological and/or exploitation reasons)

There are four systems : the Sunda Strait, the Makassar Strait, the Bali Strait and the South China Sea.

- the Sunda Strait is the working field of Bogor University;
- the Makassar Strait, as a transit area is a place of great interest. Migration phenomena, occurring in June when the catches fall, could be more understood by deep studies (salinity, species biology,etc.) considering that a part of the total population of Java Sea is composed of migratory species (*Decapterus*);
- the Bali Strait biomass will be monitored;

- the South China Sea seems to be a priority for the authorities. Genetics studies are and will be carried out. Although the stocks leaving there cannot be considered as a part of the Java Sea biomass, acoustic surveys will be achieved. Recruitment will be studied. Because these moving stocks are related to the neighbourhood, it seems indispensable to have a "regional-acoustic" cooperation with the coastal nations that share these stocks, such as : Vietnam, Malaysia, Taiwan, Thailand, China,etc. This political matter could be a difficult problem to overcome. To conclude this chapter, it has been specified that BPPT was conducting a program called "Sea Waters" where three places were concerned : the Makassar Strait, the Malacca Strait and the Karimata Strait. Commercial ships might be involved for sampling across the area.

E.E.Z.

The research vessel Baruna Jaya IV is planned to cover the whole area. The ship is equipped with a EY 500 echo-sounder.

The Pacific side and the Indian side have the same priority. The Pacific side has practically no data on monsoons and their related currents, the upwelling of New-Guinea, productivity and phytoplankton. The Indian side has to be focused on, because Indonesia is the breeding ground of tunas caught in Australia.

Working area proposals have been done : North Sulawesi; South China Sea; Makassar strait; Arafura Sea. Because of budget limitation, Banda Sea and Biak surroundings are not confirmed.

REGION *and the role of Indonesia in South-East Asia*

Acoustic has become a tool of primary importance in Indonesia. Many new acousticians have been formed, but there is still a lack of electronics engineer of high level obviously requisite to keep such sophisticated equipment in good conditions.

Acousticians are still scattered everywhere in different institutes and institutions. The first step, after this burst of scientists, is to organize a national-scale network in order to coordinate all the scientific teams and the planning of the research vessels, in Indonesia. Indonesia universities, BPPL, BPPT, LOAN involved in acoustics, are the first concerned.

This step could be then followed by the accomplishment of an ASEAN network under Indonesia's leadership since acoustic experts in Asia are very scarce.

CONCLUSION

The results presented during the seminar AKUSTIKAN 2 allow to define the main characteristics of the pelagic populations of the Java Sea.

The seasonal study of the structures, the abundance and the behaviour shows the existence of three population strata: oceanic, neritic and coastal. Their geographical limits vary according to the seasonal waters movement. In dry season, there is an abundance gradient, from West to East. In wet season, this gradient is less marked and a second one can be found from the shoreline to the open sea. An inter-annual follow-up of the environment richness can be envisaged by performing West to East tracks through the Java Sea, at each hydrological season.

A part of the population seems to be semi-pelagic species and thus partially undetectable during the diurnal phase. At night, thanks to circadian and vertical migratory moves, this group can be detected. Nevertheless, its density evaluation remains difficult to assess due to the concomitant migration of micro fauna such as plankton and larvae.

Acoustic densities measured in October 1993 and February 1994 show that about 70% of the biomass found in dry season, vanish from the Java Sea in wet season. This seasonal migration, etched on certain species biological cycle, can be considered as linked with two vital functions : feeding and breeding. Immigration occurs when the environmental conditions are favourable to repopulating. Cohort evolutions, analyzed by dynamics biologists of the Project, point out that the input of the young recruits of 6 months old into the fishery, occurs generally in May (Potier, in press). Knowing the fact that the great migration takes place in November or December, we can guess that the spawning happens just before that departure. Even if this phenomenon does not concern the whole migrating stock, because a part of it is oceanic, it seems anyway that the Java Sea represents an important nursery. Observations in this way, during the wet monsoon, could allow to localize the most privileged places, called retention areas.

All along the year, the resident part of the stock seems to move within the Javanese basin. More precised knowledge of these moving, undoubtedly linked with the seasonal cycle, would require regional follow-up.

However, the acquired results must not mask the fact that some remaining uncertainties must be removed. Identification sampling performed during the surveys has not given convincing results. One will have to undertake fishery experiments using other gears and /or other strategies aiming at improving the volume of capture. We can quote : the use of bigger trawls hauled at higher speed and the usage of fishermen's tactics outside the traditional fishing grounds. In this manner, one could better specify the seasonal zones of the species and the targeted species proportion within the present biomass.

School density in the Java Sea is very low but in the coastal stratum. The subsurface layers are generally poor that can be the result of avoidance. It looks then necessary to undertake series of observation to answer that question.

Among these tasks we can propose :

- the simultaneous use of an echo-sounder and a side scan sonar. This will help to get a better sampling and to specify the range of the avoidance in front of the vessel.
- parallel prospecting involving steam and sailing boats to detect a superficial avoidance due to the noise.

In conclusion, Acoustics within the Pelfish Project program has notably improved our knowledge on pelagic populations of the Java Sea. We better understand the opportunity and the adaptation of the fishing strategy used at present. Acoustics technique takes henceforth a particular place in stock management. It permits to study the daily and seasonal changes of fish availability through structure analysis at different distance scales. It displays and evaluates the impact of environment conditions on the populations and allows to better apprehend the catchability variations. Then, it enables to analyze the aggregating process applied by the fishermen : their influence on the pelagic population structures and the supply of information on the fishing pressure level face to available densities. Someone has proposed a way of search during the first session. This way has demonstrated how Acoustics information can be associated with the knowledge of the capture mode. In this way, one can evaluate the level of the relationship between the stock and the fleet by estimating the impact of the fishing strategy on the fish behaviour.

Techniques applied in the Java Sea can be extended to the whole Indonesian waters. Considering their expanse and the regions still unknown, we can guess that Acoustics is one of the research tools that will undergo an important development in this country.

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LIST OF ABBREVIATIONS

AARD	Agency for Agricultural Research and Development
AZTI	Food and Fisheries Technological Institute
ASEAN	Association of South-East Asian Nations
BMG	Agency for Meteorology and Geophysics, Jakarta
BPPL	See RIMF
BPPT	Agency for Assessment and Application of Technology
CPUE	Catch Per Unit of Effort
CRIFI	Central Research Institute for Fisheries
CTD	Conductivity, Temperature, Depth
dB	decibel
DGF	Directorate General of Fisheries
EEZ	Exclusive Economic Zone
ENSO	El Nino Southern Oscillation
ESDU	Elementary Sampling Distance Unit
ESP-DB	Echo Signal Processing - Dual Beam
ESP-EI	Echo Signal Processing - Echo-integration
EU	European Union
FAD	Fish Aggregating Device
FAO	Food and Agricultural Organization
FAR	Fisheries and Aquaculture Research
FL	Fork Length

GI	Gonad Index
GPS	Global Positioning System
GSI	Gonado Somatic Index
IFREMER	French Institute for Research at Sea
INES	Acoustic interface for numerisation and visualisation
ITB	Bandung Institute of Technology
IPB	Bogor Institute of Agriculture
kHz	Kilohertz
MOVIES	Integration and storage module
Nm	Nautical Mile
ORSTOM	French Research Institute for Development Through Cooperation
PELFISH	Java Sea Pelagic Fishery Assessment Project
PPP0-LIPI	Institute of Oceanology of the Indonesian Academy of Sciences
RIMF	Research Institute for Marine Fisheries
STP	College of Fisheries
TL	Total Length
TS	Target Strength
UNHAS	Hasanudin University
UNDIP	Diponegoro University
UNPATI	Patimura University
VPA	Virtual Population Analysis