ifremer

direction des ressources vivantes

Jacques Fuchs *(DRV/Paris)*
Jean-Louis M.Martin *(Crema L'Houmeau)*
Jacques Populus *(DEL/AO/ Brest)*
Novembre 1998 - R.FINAL.DRV/RA/RST/98-05

Assessment of tropical shrimp aquaculture impact on the environment in tropical countries, using hydrobiology, ecology and remote sensing as helping tools for diagnosis

Rapport final du contrat européen RS3 - CT 94-00284

Landsat TM image, August 1996 over the Dipasena and Bratasena shrimp farming complexe, Northern Lampung province, Sumatra, Indonesia (Approx. scale 1/300 000).

ASSESSMENT OF TROPICAL SHRIMP AQUACULTURE IMPACT ON THE ENVIRONMENT IN TROPICAL COUNTRIES, USING HYDROBIOLOGY, ECOLOGY AND REMOTE SENSING AS HELPING TOOLS FOR DIAGNOSIS

J. Fuchs[(1)] , J-.L. M. Martin[(2)] , J. Populus[(3)]

[(1)] IFREMER, Technopolis 40, 155 rue Jean-Jacques Rousseau, 92138 Issy-les-moulineaux, France

[(2)] CREMA-L'Houmeau, BP 5, 17137 L'Houmeau, France

[(3)] IFREMER, BP 70, 29280 Pouzane, France

Rapport final du contrat Européen TS3-CT 94-00284. Rapport Interne de la Direction des Ressources Vivantes de L'IFREMER, DRV/RA/RST/98-05, 1998.

FICHE DOCUMENTAIRE

Type de rapport :	RAPPORT FINAL de Contrat Européen (STD3/DG12)
Numéro d'identification :	DRV/RA/RST/98-05
Validation :	DRV/RA
Date de publication :	Septembre 1998
Diffusion :	libre ☑ restreinte ☐ interdite ☐
Nombre de pages :	263
Bibliographie :	oui
Illustration(s) :	oui
Langue du rapport :	anglais

Titre et sous-titre du rapport :
"Assessment of tropical shimp aquaculture impact on the environment in tropical countries, using hydrobiology, ecology and remote sensing as helping tools for diagnosis".

Titre traduit :
"Etudes des interactions entre l'aquaculture des crevettes Péneides et l'environnement côtier en Asie et dans le Pacifique à l'aide de l'hydrobiologie, de l'écologique et de la télédétection".

Auteur(s) principal(aux)	**Organisme/Direction/Service/Laboratoire**
Fuchs Jacques	Ifremer DRV/Paris
Martin Jean-Louis M	Crema-L'Houmeau
Populus Jacques	Ifremer DEL/AO/Brest

Collaborateur(s)	**Organisme/Direction/Service/Laboratoire**
Garen Pierre, Cuzon Gérard	Ifremer DRV/RA/Tahiti
Lemonnier Hugues	Ifremer DRV/RA/Nouvelle-Calédonie
Bailly Denis	Ensar
Guelorget Olivier	Université Montpellier II
	ITC - Hollande
	ION - Vietnam
	BADC et BPPT - Indonésie

Commanditaire :

Union Européenne - DG12
200, rue de la Loi
B - 1049 Bruxelles

Réalisateur(s) :

IFREMER - DRV/Paris
155, rue Jean-Jacques Rousseau
F - 92138 Issy-Les-Moulineaux cedex

Coordonnateur : Jacques Fuchs (E-mail : jfuchs@ifremer.fr)

Titre du contrat : Contrat N° TS3 - CT 94 00284	**N° de contrat Ifremer** : 94/1212147/NF

Cadre de la recherche

Programme :	A3 (interaction aqua/Envir)	Convention :	
Projet :	Européen DG12/STD3	Autres (préciser) :	

Campagne océanographique :

FICHE DOCUMENTAIRE

Résumé :

Le programme mis en oeuvre par la DRV (Paris, CREMA-L'Houmeau, DEL/AO Brest, COP Tahiti, GIE/RA Nouvelle Calédonie), dans le cadre d'un projet européen STD3 « (Sciences et Technique au Service du Développement », en collaboration avec l'Université de Montpellier II, l'Ecole Nationale d'Agronomie de Rennes, l'ITC (Hollande), l'Institut Océanographique de Nha Trang (Vietnam), le BADC de Jepara et le BPPT de Jakarta (Indonésie), avait pour but la mise au point de méthodes permettant d'améliorer la sélection des sites ainsi que le suivi du développement et de l'impact de l'aquaculture des crevettes Péneides en milieu tropical pour éviter la surexploitation. Quatre axes de recherche ont été définis :

a) identifier la nature et quantifier les rejets de déchets issus de ce type d'aquaculture,
b) définir les caractéristiques écologiques des écosystèmes susceptibles d'accueillir l'activité aquacole et suivre leur évolution sous l'influence des rejets,
c) déterminer l'influence de la gestion des fermes et des ressources (aspects économiques) sur les performances de productivité,
d) déterminer la capacité de la télédétection comme outil de diagnostic d'impact à l'échelle de la région,
e) mener un programme de formation d'étudiants et jeunes chercheurs Vietnamiens et Indonésiens.

Les travaux traitant de l'influence des paramètres zootechniques ont montré que la quantité de déchets générés par kilogramme de crevette produit augmentait proportionnellement à la densité d'élevage des crevettes. Un tableau de la production potentielle des déchets est proposé en fonction des paramètres zootechniques utilisés dans les différents types d'élevage.

L'étude des principaux écosystèmes accueillant l'aquaculture ou susceptible de l'accueillir, en Asie et dans le Pacifique, a conduit à en définir trois grands types, caractérisés par la capacité à renouveler l'eau de mer (notion de confinement) et par la pression des apports continentaux, exprimée en termes de matières en suspension, de matière organique détritique, de structure des populations phytoplanctoniques et bactériennes en particulier. Une échelle de productivité potentielle des écosystèmes est proposée en fonction de leurs caractéristiques.

L'étude socio-économique menée dans 4 systèmes d'exploitation (du traditionnel à l'intensif, i.e. 2 à 30 crevettes au mètre carré) en Indonésie ne fait pas apparaître de différences en terme d'analyse coût-bénéfice. On note cependant que lorsque l'intensification est menée sans amélioration des pratiques et de la gestion de l'eau, les risques de mortalité augmentent en même temps que les résultats économiques diminuent. Dans le cas du delta du Mékong les fortes contraintes environnementales, la difficulté d'accès aux techniques ne militent pas pour une intensification des élevages sauf dans certains cas particuliers.

La télédétection satellitaire par imagerie Landsat ou Spot a permis d'obtenir une perception globale des charges turbides en présence, ainsi qu'une illustration du transport sédimentaire littoral. Une cartographie instantanée des matières en suspension totales dans les eaux côtières a été établie, et notamment le gradient côte-large. La cartographie de l'occupation du sol (grands ensembles culturaux, surfaces aquacoles, mangroves), a été réalisée à deux dates (1991 et 1995) et ses changements illustrés : modifications des activités (conversion de rizières en bassins) mais aussi érosion de certaines parties du littoral. La télédétection aéroportée, malgré des difficultés de mise en oeuvre, a permis de cadastrer les bassins d'aquaculture, leur état de mise en eau, leur type d'eau, leur distance à la mer, que l'on a pu exploiter ensuite au sein d'un Système d'Information Géographique (SIG).

L'ensemble de ces résultats a permis d'émettre des recommandations en matière de sélection de site avec l'identification et la sélection d'un nombre limité d'indicateurs écologiques du milieu (matière en suspension totale, matière organique particulaire, cyanobactéries, bactéries sulfato-réductrices) adapté à chaque écosystème. Des recommandations ont également été formulées afin d'améliorer et développer les systèmes d'exploitation existants, notamment en Indonésie. Ces travaux ont conduit à réaliser un prototype de Système d'Informations Géographique pour la province de Lampung (Sud Sumatra). Les premiers traitements permettent de montrer des tendances concernant l'évolution spatio-temporelle de la production, en fonction des paramètres répertoriés.

Ce travail a montré que les sites aquacoles et leur développement ne pouvaient être gérés qu'à l'échelle des écosystèmes et qu'il était nécessaire de suivre l'évolution de leurs caractéristiques sous la pression des activités anthropiques (y compris, bien sûr et surtout, l'aquaculture). L'approche pluridisciplinaire retenue a facilité la mise au point de méthodes, et la définition d'indicateurs, permettant de mieux appréhender la capacité d'un site à supporter l'aquaculture et de suivre son évolution.

Mots-clés : interaction aquaculture - environnement, aquaculture crevettes, critères écologiques et socio-économiques, sélection de sites, suivi du développement, télédétection, SIG.

FICHE DOCUMENTAIRE

Abstract :

After a period of rapid development of the sites (an increase in both reared surface area and production), tropical shrimp aquaculture is currently being faced with critical problems due to economical and ecological constraints. In many countries with favourable conditions for shrimp aquaculture such as Indonesia or Vietnam, sites are often badly selected and/or over-exploited. This conducts to some extent to decreases or collapses in the production due to the difficulty in predicting the maximum production capacity of the sites. Furthermore, it appears that production sustainability depends on many factors among which socio-economy and ecology are of prime importance.

The STD3 project titled « Assessment of tropical shrimp aquaculture impact on the environment in tropical countries using hydrobiology, ecology and remote sensing as helping tools for diagnosis » was initiated in 1994, with the aim to study the sustainability of marine shrimp aquaculture in tropical areas, mainly Indonesia and Vietnam, through the following tasks: (i) improve site selection and study the impact of aquaculture on marine environments presenting a variable sensitivity to organic sewage, (ii) analyse the socio-economical aspects and profitability of the aquaculture industry and of common resources (iii) use remote sensing and geographical data bases for diagnosis and monitoring of site degradation (iv) reinforce the capacity of Asian scientists through training.

Several aquaculture sites have been investigated in the Lampung region (South Sumatra, Indonesia), the Mekong delta (Vietnam) and on the West coast of New-Caledonia, providing a large range of typical ecosystems encountered in Asia and in the Pacific, from coralline sites to coastal plains with mangrove and deltaic areas. The study concerned the spatial structure and seasonal influence of these ecosystems, the temporal variation during the course of the project (3 years) and the relation between the ecological structure and farm productions.

Remote sensing provides a synoptic vision over large land expanses. Several scenes were processed for land-use mapping using conventional classification techniques. Concerning water quality assessment, a general relation for the Java sea was found between image and field data in terms of total suspended matter. Applying this relation to a new site in Sumatra has provided an initial approach to water type and, together with land use mapping, a preliminary assessment of the suitability of the area to shrimp aquaculture development.

Socio-economic research has been focused on the identification of needs for collective action, including public policy, in the perspective of shrimp farming sustainability. The main concern is in the regulation of shrimp farming intensification and extensification at the scale of coastal ecosystemic entities in a common property resource management perspective. The common considered here is coastal water quality. Comparing the local development profiles and the institutional grounds for the design and implementation of collective management rules shows that variables such as land tenure system, farm owner socio-economic profile, social homogeneity or heterogeneity of the farmers are key factors to analyse the potential for sustainability. The definition of water quality and the possible means to ensure its collective management are discussed. The main conclusion is that the economic incentives to farming development are strong but there is no significant difference among traditional, semi-intensive and intensive systems in terms of economic efficiency or wealth distribution.

The description of the functioning of the different kinds of ecosystems make it possible to give an advice concerning the positioning of the activity inside the ecosystem, and furthermore to have a reference state in order to determine the impact of the activity on the coastal environnement. This impact can be summarized as an increase in the concentration of total suspended matter, of particulate organic matter and of sulfate reducing bacterias. This organic matter is either issued from rearing activities or from telluric origine, due to mangrove eradication when building the ponds.

An evaluation of the relationship existing between productivity and characteristics of each ecosystem has been conducted by correlating ecological indicators data (concentration of total suspended matter, particulate organic matter, chlorophyll, percentage of pheopigments in total pigments and cyanobacteria and sulfate-reducing bacteria in water and sediments) with the average production of the farms. This comparison lead to the compilation of a scale of observed production integrating the range of these environmental parameters with shrimp production levels, bound to facilitate the positioning of shrimp farming in relation with the confinement level of each ecosystem.

Lastly, all geographic data originated from the various compartments of the study have been geo-referenced and loaded into a geographical information system. This allows to display any query made on spatial variables and their related statistical data, including their variations over the last few years and to reveal patterns and phenomena otherwise not obvious.

Keywords : impact assessment, coastal environment, shrimp culture, biological and socio-economic criteria, site selection, remote sensing, GIS

List of scientific participants

Ifremer

Raphaël Brizard - Ifremer - New-Caledonia
Gérard Cuzon - Ifremer - Tahiti
Luc Della Patrona - Ifremer - New-Caledonia
Jacques Fuchs* - Ifremer - Paris, *General coordination*
Pierre Garen - Ifremer - Tahiti
Jose Herlin - Ifremer - New-Caledonia
Christophe Jamoneau - Ifremer - Tahiti
Lucette Jouassard - Crema - La Rochelle
Hugues Lemonnier - Ifremer - New-Caledonia
Jean- Louis M.Martin* - Ifremer - Crema - La Rochelle, *Scientific coordination, task 1*
Jacques Moriceau - Ifremer - Tahiti
Jacques Populus* - Ifremer - Brest, *Scientific coordination, task 4*
Dominique Pham - Ifremer - New-Caledonia
Bernard Troin - Ifremer - Tahiti
Yves Veran - Ifremer - New-Caledonia

Université Montpellier

Annouk Favry
Olivier Guelorget*, *Scientific coordination, task 2*
Anne Lefebvre

Université Bretagne Occidentale - Cedem

Denis Bailly*, *Scientific coordination, task 3*

ENSAR - Rennes

David Guyomard
Pascal Raux

ITC - Holland

Joan De Meyere, *Training SIG*

ION - Nha Trang - Vietnam

Dr. Vo van Lanh - Administation Official
Dr. Nguyen Tac An* - Scientific Official, *Scientific coordination, Vietnam*
Mr Nguyen Thanh Van - Secretary
Mr Vo Duy Son - Researcher
Mr Le Lan Huong - Researcher
Mr Le Trong Dung - Researcher
Mr Le Tran Dung - Researcher
Mr Duong Trong Kiem - Researcher
Mr Pham Huu Tam - Researcher
Mr Pham Van Thom - Researcher
Mr Dao Tan Ho - Researcher
Mr Bui Quang Nghi - Researcher
Mr Nguyen Phi Phat - Technician

BPPT - Jakarta - Indonesia

Dr. A.Karsidi - Director Technology for Natural Resources Inventory
Mr Agus Wibowo*- Researcher, *Scientific coordination, BPPT*

BADC - Jepara - Indonesia

Dr. Made Nurdjana* (1994-1997) ; Dr. Iin Djunaidah (1997) - Director BADC, *Scientific coordination, BADC*
Mrs Wiwik Malistyani & Arief Prihaningrum - Researchers (socio-economy)
Mrs Woro Hastuti & Mr Bambang Sumartono - Researchers (Gis and remote sensing)
Mr IBM Suastika Jaya - Researcher (hydrobiology and ecology)

Dinas Perikanan - Indonesia

Mr Badruddin

SUMMARY

INTRODUCTION

Author: Jacques Fuchs Ifremer/Paris

1. Context of shrimp farming in Asia and the Pacific

Shrimp farming has undergone extraordinary expansion since 1980. Production increased from less than 50,000 metric tons to almost 700,000 metric tons in 1990 (920,617 metric tons in 1994, New 1997). At the same time, production of marine shrimp from the capture fisheries only rose by 11 % between 1985 and 1994. Shrimp farming currently accounts for 25 % of world production, for a value of around 6 billion US$. One in every three shrimp that we now consume comes from aquaculture.

In this context, Asia plays an important role, contributing to more than 80 % of total shrimp farming production, for an average total of 748,3000 metric tons in 1994. Four Asian countries (Thailand, Indonesia, Philippines and India) rank amongst the top five producers as shown in **table 1**.

Table 1. 10 top producers - Marine shrimp farming *(in New 1997).*

1994 RANK	Country	1994 (mt)
1	**Thailand**	267,764
2	**Indonesia**	167,410
3	**Ecuador**	98,731
4	**Philippines**	92,647
5	**India**	91,974
6	**China**	63,872
7	**Vietnam**	36,000
8	**Bangladesh**	28,763
9	**Mexico**	13,454
6	**Others**	60,002
Totals		920,617

Major improvements have been made within the last 20 years, including mass production of post-larvae in industrial hatcheries and production of pellets with high protein levels, which resulted in an increase in pond-stocking density and yields. During the last two decades, stocking density of the seed has increased from a few individuals to 40 or 50 per square metre. In his review of main factors of success in shrimp farming, Csavas (1994) shows the very close correlation between the growth of shrimp production and the production of post-larvae from hatcheries in Taiwan and Ecuador. At the same time, the quantity of manufactured pellets used in shrimp production has increased dramatically.

Nevertheless, after doubling, world-wide shrimp production decreased in 1992 and has tended to remain stable since then, despite an increase in total pond area. Several Asian countries suffered drastic collapses over the last ten years, as for example Taiwan in 1988, China, which soared to a peak of around 220,000 metric tons in 1991, before collapsing to 88,000 metric tons in 1993, and Indonesia, which stabilised its production at 167,000 metric tons in 1994, after slight decline. Thailand is the only country in the region to show a steady increase in its production from 1984 to 267,000 metric tons in 1994. This was achieved despite a severe crisis thanks to strict farm management, which curbed sludge discharge into the environment and reliable new rearing techniques based on limited water exchange (A. Kongkeo, 1997). As shown by Csavas (1994), the growth curve of farmed shrimp production is similar to the theoretical growth curve of a market commodity featuring three phases: development, growth, and maturity. In the last phase, critical problems arise due to economic and ecological constraints.

The main reason for this decrease is deteriorating water quality and the emergence of numerous pathogens. Excessive and unplanned farm development and poor pond management have exacerbated this trend. In addition, the spread of bacterial and viral diseases was facilitated by the use of wild breeders and the transfer, without sanitary precautions, of exotic species susceptible to host latent pathogens between various tropical countries (Johnson, 1994).

These crises clearly reflect the strong relationship between farming activities and global environmental conditions. It is now well established that aquaculture is so dependent on the environmental quality of the sites that it cannot succeed in an unsuitable environment. Aquaculture has to be seen as the best guarantee for environmental protection (PAP, 1996). Nevertheless, the intensification of shrimp farming, in terms of surface areas, number of crops per year, and density per ha, has resulted in severe disruption of the ecosystems in many countries, with the destruction of the green belt (mangrove) and the conversion of large paddy fields into shrimp ponds. In many countries with favourable conditions for shrimp farming, such as Indonesia or Vietnam, sites are often poorly selected and/or over-exploited due to the difficulty in predicting maximum production capacity.

Three objectives have to be met to promote truly sustainable shrimp farming: (i) economic viability (ii) preservation of the whole environment (iii) social acceptability. This new comprehensive approach, backed up by sound research arguments and widely promoted by decision-makers, should curb disorderly development in the future.

2. How can research contribute to sustainable shrimp farming?

Since 1990, many scientific congresses or workshops (e.g. "Swimming Through Troubled Water", the special session on shrimp farming at World Aquaculture '95') have been devoted to the problem of shrimp farming sustainability and a lot of literature has been published by authors from national or international organisations: Csavas (1994), Rosenthal (1994), Landesman (1994), Currie (1994), Chamberlain and Rosenthal (1995), Jory (1995).

Several ways are currently being investigated to maintain and develop shrimp productivity in order to meet the ever increasing demand of the three main markets: Japan, USA and Europe, and a number of new markets in Asia (China, etc.).

One avenue of research is to study the production system itself in order to improve sanitary conditions and pond management (reduction of waste discharge) and to select strains that are well adapted to captivity.

To achieve these objectives, basic and applied research are needed in the following major fields:

- Knowledge of species biology, including physiology and nutrition,
- Technological improvement (pond design, water treatment),
- Health management,
- Selection et genetic improvement,
- Quality of final products.

Another avenue of investigation, which is a complement to the first, is to promote legislation to regulate farm settlement on coastlines and in mangrove areas in accordance with the carrying capacity of each site. Governments need sound scientific arguments to draft regulations for aquaculture development, water use, sanitary procedures and waste discharge conditions (Beverage et al 1991, Chua, 1992, Munday et al 1992).

Maintaining a beneficial environment for aquaculture and other players requires detailed study of the interrelations between environment and resources. This is particularly important in the case of shrimp farming, which interacts strongly with fragile tropical coastal environments (mangroves areas, closed bays, coralline sites, etc.). The major issues involve:

- the definition of precise site-selection criteria, taking into account the actual capacity of each ecosystem to tolerate and assimilate waste produced by shrimp farming,
- the improvement of water and pond management to minimise effluent discharges,
- the investigation of the social and economic aspects of shrimp farming in order to reduce production costs and improve the policies and regulations intended to facilitate its integration in coastal zones,
- the development of management tools for decision-makers to provide better control of shrimp farming development.

The research carried out in the STD3 on the interrelations between the environment and resources is in keeping with this second avenue of investigation.

3. Objectives and expected outcome of the STD3 programme

3.1. Objectives

The general and long-term objective of the three-year STD3 programme, "Assessment of the impact of tropical shrimp farming on the environment using hydrobiology, ecology and remote sensing as helping tools for diagnosis" was to contribute to the development of marine aquaculture in tropical areas, taking into account the preservation of an environment that is beneficial both for aquaculture and other purposes.

More specifically, four main objectives were set for the project:

1. to study the impact of tropical shrimp farming development on marine environments with variable sensitivity to organic sewage: coastal mangrove areas in Indonesia, coralline sites in Indonesia and New-Caledonia, delta mangrove in Vietnam ;

2. to enhance site-degradation survey methodologies, previously developed during a 4-year research programme in the Indonesian component of the AADCP programme (1991-1994), testing the possibility of remote-sensing technologies as a tool for monitoring the environmental changes and evaluating the impact of aquaculture sewage on water quality over the whole geographic area (bay, delta, etc.) ;

3. to set up a GIS applied to aquaculture using the hydrobiological, ecological, socio-economic and remote sensing data collected on the selected sites and to test it as a tool for diagnosis and coastal management decision-makers ;

4. to reinforce the capacity of the Indonesian partners to conduct integrated studies using remote sensing and GIS, to train Vietnamese partners in pond management and environmental surveys and enhance links between EU and Asian researchers.

3.2. Activities

The keys activities were:

1. Qualification and quantification of sewage produced by shrimp farming at the level of the animals (excretion under different environmental and feeding conditions) and at the level of the ponds where shrimps are reared under different stocking conditions, ranging from extensive to almost intensive conditions (1 to more than 150 PL/m^2) with different water renewals.

2. Evaluation of the environmental impact and the evolution of organic wastes produced by shrimp farming in 3 geographic areas where different ecological conditions and aquaculture development stages are encountered in tropical countries.

3. Farm management and the economics of common resources management .in different contexts and the definition of specific indicators that rapidly provide decision-makers with a detailed view of the situation of shrimp development.

4. Testing remote sensing and airborne technologies as tools for monitoring environmental changes and evaluating the impact of shrimp farming at the level of whole ecosystems (bays, deltas, etc.).

5. Training Asian scientists in the field of aquaculture (pond management), environmental surveys and monitoring, remote sensing and GIS technologies. Increasing links between EU and Asian researchers through frequent surveys, and taking part in symposia and workshops.

3.3. Expected Outcome

The programme was expected to increase scientific knowledge about qualifying and quantifying the existing relationships between the environment and shrimp farming under different site and exploitation conditions in Southeast Asia and in the Pacific.

The expected result of the STD3 programme was the development of specific methodologies for improving site selection of sites and experimental management tools providing better monitoring and control of aquaculture development and, consequently, preventing overexploitation. The training programme attached to the project was to help increase the scientific knowledge of Asian partners and reinforce cooperation between ASEAN and EU countries.

4. Description of the different tasks and time table

The STD3 programme was organised around 5 complementary tasks:

Task 1. Identification and quantification of sewage produced by shrimp farming at the level of animals and ponds under semi-intensive (10-30 post-larvae/m^2) and intensive conditions (50-150 PL/m^2).

Participants: Ifremer Tahiti, New-Caledonia, Crema.

Task 2. Characterisation of ecosystems and follow-up of their evolution under the impact of shrimp farming development in 3 geographic areas
a) Mekong delta ecosystem in Vietnam,
b) mangrove and coralline sites in Lampung Province, South Sumatra, Indonesia,
c) coralline site with mangrove in North and Central parts of New Caledonia.

Participants: Badc, Ion, Ifremer/Crema, University of Montpellier.

Task 3. Technical and economic survey of farm management and socio-economic analysis of common resources management in Indonesia (South Sumatra) and Vietnam (Mekong delta).

Participants: Ensar, Badc, Ion.

Task 4. Remote sensing tools and Geographic Information System.

Participants: Bppt, Badc, Ifremer/Del/Ao, Itc.

Task 5. Training courses in pond management and bacteriology (Vietnam), Environmental survey and monitoring (Indonesia- BADC) and GIS technologies (Indonesia - BPPT).

Participants: Ifremer, University Montpellier II, Ensar, Itc, Badc, Bppt, Ion.

The work programme is presented in **table 2**:

Table 2. STD3 work programme 1994-1997.

	1994	1995	1996	1997
Task 1. Quantification and Qualification of sewage				
a) animal level (Tahiti)	■	■	■	■
b) pond level(Tahiti, New Cal)	■	■	■	■
Task 2. Characterisation of ecosystems				
Indonesia	■	■	■	
New- Caledonia	■	■	■	
Vietnam		■	■	■
Task 3. Farm Management				
Indonesia		■	■	
Vietnam			■	■
Task 4. Remote sensing (Indonesia)				
Task 5. Training MsD		■	■	
Work meetings				■

5. Role of partners and specific work programme

The cooperative programme involved 4 Institutes in 2 EU countries: ITC Enschede in the Netherlands, IFREMER centres of La Rochelle, Tahiti, New-Caledonia and Brest, the University of Montpellier II and ENSAR (Ecole Nationale Supérieure d'Agronomie de Rennes), as well as 3 Institutes in 2 Asian countries: BADC Jepara (Brackishwater Aquaculture and Development Center) and BPPT Jakarta (Remote Sensing and GIS) in Indonesia, ION (Institut Océanographique de Nha Trang) in Vietnam.

The work programme for each partner was defined taking into account the geographic and thematic specificity of each partner:

- **Aquaculture and Development Centre - Jepara - East Java**

  BADC acted as the Indonesian partner for the research concerning Tasks 2, 3 and 4 of the programme:

  - acquisition and treatment of hydrological, ecological, and socio-economic data on selected sites in Lampung (South Sumatra) in order to assess the environmental impact of aquaculture development ;
  - introduction of data related to aquaculture in the GIS system ;
  - training of three BADC scientists in the environmental field (Msc in Indonesia).

- **BPPT (Badan Penkajian Dan Penerapan Tecknologi) - Jakarta - Indonesia**

  BPPT focused its research on tasks 3 and 4 of the STD programme:

  - acquisition and analysis of remote sensing data, research into correlations between ground and remote sensing data. Participation in the construction of a GIS in collaboration with IFREMER, ITC and BADC
  - training programme in remote sensing and GIS in ITC for MsC preparation.

- **ION (Institut Océanographique de Nha Trang) - Nah Trang - Vietnam**

  ION acted as the Vietnamese partner in the STD3 programme and was involved in Tasks 2, 3 and 4:

  - study of the organisation and functions of the Mekong delta (Vun Tau, Cangio, Tra Vinh, Ca Mau). The objective was to determine how and where to place aquaculture in the delta system, according to the environmental conditions. Remote sensing was used to evaluate the land use in the delta
  - participation in the socio-economic study of aquaculture production in the Mekong delta
  - training course in environmental surveys (University of Montpellier) and pond management (Tahiti).

- **IFREMER, Direction of Living Resources**

  The Direction of living resources coordinated the programme in Paris and had 4 laboratories involved in the programme:

  - <u>Crema: Centre de Recherche Ecologie Marine et Aquaculture de L'Houmeau</u>
    Crema participated in Tasks 1, 2, 3 and 4:

    · coordination of the research on quantification and qualification of sewage produced by shrimp farming

    · hydrobiological aspects of the surveys and participation in interpreting the remote sensing data

    · field training of Asian scientists in hydrobiology, aquaculture and environment.

  - <u>Research centres in Tahiti and New Caledonia</u>
    The Centre Océanologique du Pacifique in Tahiti and Ifremer in New Caledonia worked specifically on Task 1.

    . COP/Tahiti studied the identification and qualification of sewage at animal level (excretion) and at pond level in an intensive range of densities (50 to 150 Pl/m^2).

    . The Station de St Vincent in New-Caledonia, participated in Tasks 1 and 2:

      - study at the level of ponds in a range from 1 to 30 PL/m^2 (semi-intensive),
      - site selection where different degrees of development are encountered and acquisition of hydrological and ecological data.

- Ifremer: DEL/AO - Brest
  The Coastal Environment laboratory developed the remote sensing and GIS system applications for coastal zone management. It coordinated Task 3 of the STD programme with ITC and it was responsible for the following actions in particular:
  - supervision of the remote sensing acquisition for satellite images and organisation of an aerial survey for CASI acquisition in Indonesia,
  - data processing, jointly with BPPT,
  - correlation between RS data and ground data,
  - coordination of a GIS prototype for aquaculture to be set up in Indonesia.

- **University of Montpellier**

  The Marine hydrobiology laboratory participated in Tasks 2 and 4:
  - conduct the ecological aspects of the environmental impact study of shrimp farming in Indonesia, Vietnam and New-Caledonia,
  - training of Asian staff in ecology (bacteriology).

- **National Institute of Agronomy - Rennes (ENSAR)**

  ENSAR supervised and coordinated the socio-economic research programme carried out in Indonesia and Vietnam and played an active role in the socio-economic training course for Asian scientists.

- **ITC - The Netherlands**

  ITC was involved in training a BPPT scientist in GIS. ITC's experience in remote sensing and GIS applied to environmental cases in tropical areas helped in the design of the GIS prototype.

6. References

Beveridge M.C.M. and L.G. Ross (1991) . Environment, site selection and planning: the role of geographic information systems in aquaculture. IFS Regional Workshop on Ecology of Marine Aquaculture, Osorno, Chile, 24 p.

Chamberlain G. and H. Rosenthal (1995). Aquaculture in the next century, opportunities for growth challenges of sustainability. *World Aquaculture (26) 1, March 1995*: 21-25. *Bangkok, January 29-February 2, 1996. Abstract.*

Chua T.E., (1992). Coastal aquaculture development and the environment. The role of coastal area management. Mar.Pollut.Bull., 25 (1-4): 98-104 p.

Csavas I., (1994). Success of shrimp farming. *World Aquaculture (25) 1, March 1994*: 34-56 p.

Currie D.J., (1994). Sustainable aquaculture in developing countries, who can make it happen ? *World Aquaculture (25) 4, December 1994*: 20-25 p.

Johnson S.K., (1994). Dissemination of exotic diseases of shrimp....is a control policy attainable ? *World Aquaculture (25) 4, December 1994*: 30-38 p.

Jory D.E., (1995). Marine shrimp farming development and current status, Perspectives and the challenge of sustainability. *Aquaculture Magazine Buyer's Guide '96*: 35-44 p.

Kongkeo A., (1997) Coastal environmental management for sustainable shrimp culture in Thailand in workshop on coastal environment management for aquaculture sustainable organised by BPPT, Jakarta, 7-8 June 1997 supported by DG12: 13 p.

Landesman L., (1994). Negative impacts of coastal aquaculture development. *World Aquaculture (25) 2, June 1994*: 12-17 p.

Munday B., A. Eleftheriou, M. Kentouri and P. Divanach (1992). The interaction of aquaculture and the environment. A bibliographical review. European Union/ DG XIV/D/3, 325 p.

New B.M. (1997). Aquaculture and capture fisheries ; Balancing the scales. *World Aquaculture*, Vol 28 (2), 11-30 p.

PAP/EAM (1996). Approches pour l'aménagement de zones côtières en relation avec l'aquaculture méditerranée. PAP-10/EAM/GL.1. 28 p.

Rosenthal H. (1994). Aquaculture and the environment. *World Aquaculture (25) 2, June 1994*: 4-11 p.

CHAPTER 1 - METHODS AND RESULTS OF EACH TASK

Task 1. Identification and quantification of sewage produced by shrimp farming at the level of animals and ponds in semi-intensive and intensive rearing conditions

Authors: *J.L. M.Martin* *Crema-L'Houmeau*
G. Cuzon *Ifremer/Centre Océanologique du Pacifique*
P. Garen *Ifremer/Centre Océanologique du Pacifique*
H. Lemonnier *Ifremer - New-Caledonia*
Y. Veran *Ifremer - New-Caledonia*

General Introduction

General objective: The aim of this part of the programme is (1) to determine the parameters which, at animal and at pond level, will reduce the quantities of waste released into the surrounding environment ; (2) to quantify the waste produced by shrimp farming to be able to quantify the cause in the cause/effect relationship between waste production and its impact on the environment.

General approach: Investigations were carried out at animal and at pond level.

At animal level, waste reduction is studied by investigating the possibility of improving feed and feeding efficiency. Research concerns (i) excretion (ii) digestibility (3) low-pollution diet.

At pond level, waste reduction research concerns the improvement of management procedures, taking into account two major parameters: stocking density and water renewal in two types of rearing conditions (semi-intensive and intensive).

Expected outcome: scientific knowledge on characterisation and quantification of waste and proposals to reduce waste production.

The production of brackishwater shrimp showed a strong increase in the 70's and 80's. In 1990, world production reached some 750,000 metric tons (FAO, 1992). However, many problems arose in most of the producing countries (Thailand, Philippines, Indonesia, Ecuador). In general, the decrease in productivity of aquaculture sites was imputed to over-intensification (total surface of ponds on the same site, stocking densities, number of rearing cycles per year) leading to the deterioration of water quality in the surrounding environment (Folke and Kautsky, 1992) and of pond water and pond sediment quality (Lin, 1989 ; Phillips *et al.*, 1993). Furthermore, it has been shown that limiting factors in successful shrimp farming are often identified as inadequate management of zootechnical parameters such as over-intensification in terms of stocking density (Ray and Chien, 1992 ; Daniels *et al.*, 1995), water management (Hirono, 1992 ; Chien, 1992), inadequate formulation of feed-pellets presenting high rate of proteins or low digestibility and energy efficiency for example (Gauquelin, 1996). As a consequence, inadequate control of these parameters leads to an increase in sewage discharge for the same biomass of shrimp produced. This makes it necessary to determine the parameters which will reduce the quantities of waste released into the surrounding environment.

There is a cause-effect relationship between the quantities of waste discharged into the environment, and their impact on that environment. Deterioration of surrounding water quality will be faster as the quantities of waste discharged into the environment increase. The study of such relationships, and more specifically, the study of the impact of wastes requires the quantification and the characterisation of these types of sewage.

So, the question raised is to determine the nutrition parameters for shrimp, on the one hand, and the management of ponds, on the other hand. Control and quantification will achieve (i) a decrease in waste formation and discharge and (ii) quantification of the cause in the cause/effect relationship in the impact of aquaculture on the environment.

For a better understanding of this part of the report, two main sections will be considered. One the one hand, the work related to research at animal level (nutrition, digestion, low-pollutant diet) and, on the other hand, the work dealing with the determination of wastes at pond level, in relation to management parameters. Because each of these two main part required different conceptual and experimental approaches, they are described and discussed separately in this report.

1.1. Research conducted at animal level

Author: *G. Cuzon* *Ifremer/Tahiti*

1.1.1. Introduction

In 1996, a decision by the Supreme Court in India (New Scientist, 1996) to close all large intensive farms has thrown the country's booming shrimp industry into turmoil. Based on evidence from several studies on the ecological and economic impact of shrimp farms in coastal areas, the court ruled that all industrial scale farms within 500 meters of the high tide line have to be demolished by the end of March 1997!

From an ecological point of view, an analysis of sewage produced at animal level is useful and the example comes from salmonids (Cho *et al.*, 1982, 1991 ; Cho and Bureau, 1997) using biological (nutritional) and chemical (limnological) methods. Peneid shrimp have just recently being considered for waste coming from pond culture, with an emphasis on feed because "feed pollutes, not shellfish" to paraphrase Cho *et al.* A selection of some ingredients to assess the digestibility value is done on shrimp to add to previous data (Teshima and Kanazawa, 1983 ; Aquacop *et al.*, 1995 ; Cousin *et al.*, 1995, Cruz *et al.*, 1996 ; Faucon *et al.*, 1997).

Some research steps leading to the qualification and quantification of waste produced at animal level when shrimp are confined to a mesocosm can be summarised as follows: (i) digestibility of common ingredients: an analytical step is needed to formulate the different kind of experimental feeds, then ingestion and digestibility studies have to be carried out (ii) elaboration of low-pollution diets. Low-pollution diets (Cho *et al.*, 1991) have then been tentatively elaborated for shrimp and their beneficial effect in terms of growth and ammonia waste reduction have been verified in small volumes.

1.1.2. Digestibility of ingredients

All of the work has been carried out at Ifremer/Center Oceanologique du Pacifique in Tahiti on the species *P. stylirostris*, which is currently reared in this part of the world. Then, some parts of the work have been extended to *P. vannamei* in an attempt to produce comparative nutrition data.

1.1.2.1. Objectives

Shrimp produce an amount of feces in relation with (i) the amount of food given and (ii) the quality of ingredients mixed together to produce the pelleted feed. In this first step, digestibility of some nutrients from several common ingredients has been studied after selection by (Nedelec *et al.*, 1996) or feed manufacturers (Devresse, 1995) to make a feed suitable for shrimp. Digestibility coefficients are essential to know if any improvements on feed formulation are to be made. It provides far more reliable value than data on crude protein or crude lipid. Nevertheless, a good assessment of digestibility means a proper methodology to get enough material for further analytical work.

1.1.2.2. Material and Methods

Group of 15 *Penaeus stylirostris* juveniles reared at COP facilities have been selected and fed a local commercial feed until they reached a weight around 20-24 g. They were allotted to each of 5 PVC tanks equipped with a flow through system. Sea water was pumped from the lagoon and provided at a rate of 2l/min. Water temperature averaged 27° C ± 1, salinity remained constant at 37 ‰ and dissolved oxygen was close to 5.5 ppm. The tanks were fitted with a 5 mm mesh net to prevent shrimp from escaping. Shrimp were acclimated for 3 days to the test diet prior to feces collection, which lasted 5 days and each experiment was repeated three times (triplicate) for each diet.

Each diet was formulated to contain 0.5 % chromic oxide as an inert marker. Coarse ingredients were ground in a hammer-mill as needed to pass through a 500 µm mesh screen and mixed in a Hobart® food mixer. Minor ingredients were blended in a mortar and increasing parts of the main mix were gradually added to ensure maximum homogeneity especially for Cr_2O_3. Water was then added to the resulting mix depending on the type of starch until an adequate consistency was reached for pelleting, after which it was extruded twice using a Hobart® meat mincer fitted with a 2 mm die. Temperature of outcoming strands did not exceed 60° C. Strands were allowed to stand for about 30 min prior to being dried in an Arthur White Pilot® fluid bed dryer at 50° C for 45 min, then broken manually to less than 20 mm length and stored at +5° C. A reference diet ingredients and the respective inclusion level were: squid meal (20 %), mussel meal (12 %), native wheat gluten (15 %), lactic yeast (13 %), wheat flour (30 %) and premixes(10 %) ; then 30 % of the mixture was incorporated in a test diet as recommended by Cho *et al.*(1991) which served as a basis for digestibility studies.

Shrimp were fed two times a day, at 8.00 am and 11.30 am. Ration was adjusted daily. Every morning, dead animals and exuviae were removed and tanks cleaned. Tanks were checked every half hour for feces collection. If present, uneaten feed particles, which were dyed red, were sorted out easily from green feces strands and discarded, along with more or less reddish feces assumed to correspond to exuviae ingestion during the night. Feces were then rinsed twice with bidistilled water to avoid contamination by salt and frozen at -20° C. Samples were freeze-dried pending analysis.

In both diets and feces, chromic oxide was determined by atomic absorption spectrometry, crude protein by Kjeldahl (N x 6.25). Energy determination was calculated using a adiabatic semi-microcalorimeter PARR and values were expressed by gross energy in MJ/kg dry matter (DM). Apparent Digestibility Coefficient (ADC) was calculated according to Maynard *et al.* (1979).

$$ADC = 1 - (c_i / c_f) \times (n_f / n_i)$$

where

c_i : chromic oxide content in feed
c_f : chromic oxide content in feces
n_i : nutrient content in feed
n_f : nutrient content in feces.

Methodology evolved during the study for low amounts of material to be collected and adequate selection of a convenient marker ;

- A flat rectangular 850-litre tank with a flow-through system containing at least 30 animals, [15 to 20 g body weight] was chosen. It is the most suitable system, allowing to collect enough material in a period of 2 to 3 days to analyse protein, energy, and lipids.

- When added to a diet, casein will need to be mixed with an attractant such as krill to ease feed intake. On the contrary, squid meal in itself, will favour feed intake and provide quality protein for growth.

- Chromic oxide, marker commonly used, was not presenting enough safety for bench work. A recent study (Deering *et al.*, 1996) indicated that celite which is a calcinated diatomaceous earth (40 % crystalline silica), inert and not absorbed, could be used similarly. Moreover, celite is easily determined (Atkinson *et al.*, 1984) with the acid insoluble ash (AIA).

1.1.2.3. Results

The gross energy expressed in MJ/Kg of different fish meal, shrimp meal, soybean meal, wheat gluten, fish protein concentrate (CPSP), fish oil wheat middlings is given in **table 3**.

Table 3. Proximate analysis (in % as fed) of ingredients for practical diets (CHO for carbohydrates).

	protein (%)	lipid (%)	CHO	Gross energy MJ/kg dm	moisture (%)
US fishmeal	64	11	-	19.8	10
Chilean fishmeal	63	11	-	19.6	10
Chilean shrimpmeal	36	2.7	-	19.5	7
soybean meal	49	1.5	-	14	12
wheat gluten	78	2.6	-	21.5	9.3
CPSP	71	6.3	-	22	12
Fish oil		100	-	38	5
wheat starch	3	1	80	14.4	7

Apparent Digestive Coefficient (ADC) expressed in percentage on semi purified ingredients such as casein and squid meal are protein sources with an ADC of 90 and 95 % respectively

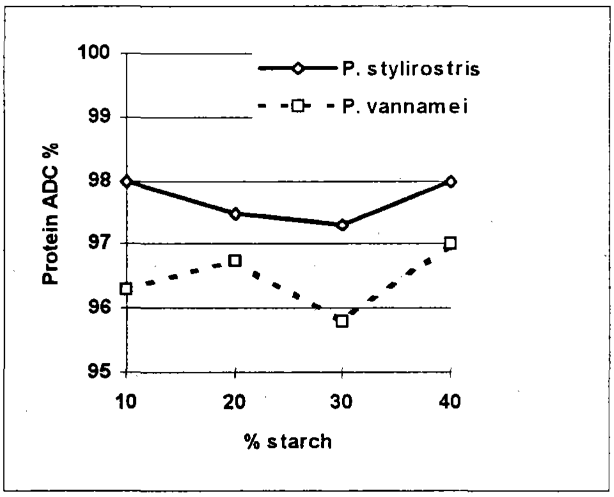
(table 4). Fishmeal values for ADC varied from 82 to 94 % and native wheat gluten is highly digestible (90 %).

Table 4. Apparent digestible coefficients (ADC) in % for nutrients coming from selected ingredients.

	ADC protein	ADC lipid	ADC starch
Casein	90	--	
Squid meal	95	-	
Fishmeal US	89		
Fishmeal Chile	94		
Shrimpmeal Chile	65		
Soybean meal	92		
Wheat gluten	90		
Fish liver oil	-	77-85	
Wheat starch	-		92.4

Apparent Digestive Coefficient (ADC) variation according to species show that *P. stylirostris* has an overall digestive capacity above the one of *P. vannamei* (**fig. 1**) ; and the level of nutrients indicates an absence of interaction between nutrients the value of ADC protein is not modified in a range of 10 to 30 % starch inclusion in the diet. The value of ADC of proteins is not affected whatever level of lipid or starch is in the experimental diet (**fig. 1**).

Fish oil is slightly lower in digestibility when its percentage is below 7 %. ADC of lipid remains stable up to 15 % dietary lipids. There is a slight drop of ADC when dietary lipids increase above 15 %, this drop could go along with a reduction in growth performances.



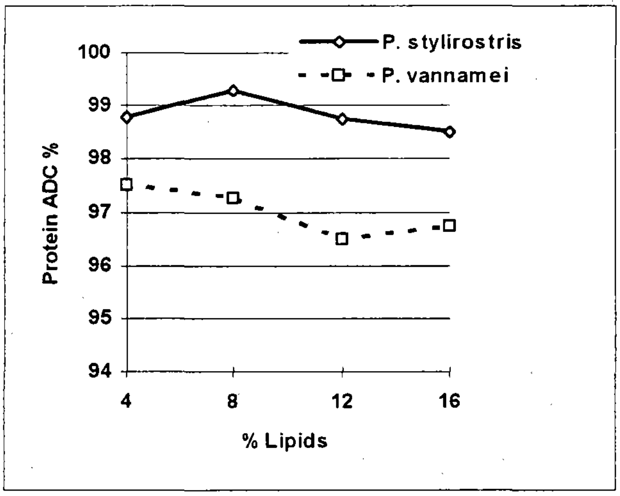


Figure 1. Apparent digestive coefficients of protein (squid+casein) in *P. stylirostris* and *P. vannamei* according to dietary lipid (fish oil) or starch (from wheat) levels in the feed.

1.1.2.4. Discussion

a) Digestibility of ingredients (caseine, squidmeal, fishmeal)

Protein sources are generally well digested by shrimp, with a special reference to native protein such as Low Temperature fish meal (LT fishmeal), freeze dried squid or wheat gluten or lactic yeast because of an absence of heat during processing. The ADC values are most of the time above 90 %. Akiyama (1989) reported ADC protein values of 99 % and 80 % for *P. vannamei* receiving casein or squid meal respectively, and it is on line with the values on *P. stylirostris* (Cousin, 1995). In spite of intestinal flora (its influence is less than what happens with terrestrial animals), undigestible starch fraction which accelerate the transit or endogenous nitrogen ingestion plus an increase of bacterial activity, by and large, ADC protein do not vary in a large range.

An exception is given with fishmeal which can vary according to its process, origin or quality. The way fish is processed and dried can influence the digestibility of the meal and consequently of the finished feed where it will be included at percentages between 30 and 40 % sometimes more. The origin of the product can make a change for example between a fishmeal from the west coast of America and another from South America (**table 4**). The quality of the protein source is as important to Penaeid growth as the level of dietary protein. For example a stale fishmeal will have a reduced ADC compared to a fresh fishmeal (Cruz *et al.*, 1996). It is evidenced that the selection of fishmeal will confer to the diet its quality ; a low pollution diet will be made preferably with a low temperature fishmeal (LT fishmeal). The question was raised of a possible interaction of other ingredients on the digestibility of the fishmeal itself. In another experiment, it was not found a significant difference in protein ADC between 10 and 50 % level of a Chilean fishmeal (Gauquelin, 1996).

Lipid digestibility can range between 78 and 88 % according the type of lipids (plant or animal origin) when fed for *P. japonicus* (Teshima and Kanazawa, 1983). The result is very similar (77-85 %) in this study or in a species such as *P. monodon* (Shiau *et al.*, 1991). Moreover, alternative energy source from lipids do not seem to be suitable for shrimp in spite of a good digestibility (the metabolic utilisation could be low).

ADC of dry matter is not taken into account at the difference with data on *P. setiferus* (Brunson *et al.*, 1997) because of contamination of feces by salt or contamination of the feed before ingestion (Metailler, 1994) which render estimates not reliable enough with an underestimation of the coefficient.

b) Differences and interaction between species

ADC of protein do not show a difference between species (95-98 %). Protein ADC remains at 96 % with *P. vannamei* whatever starch level is (**fig. 1**, left curve) *P. stylirostris* has a tiny variation between 10 and 30 % starch content. It emphasises anyway the absence of interaction between nutriments during absorption mechanisms, protein and starch ADC remaining similar.

Starch seems to be tolerated fairly well by shrimp and such variations could remain in the background noise, starch is well digested at the difference with what happens with fish. In addition, there is no real difference between raw or pre-cooked starch. Such results give a fair access to the formulation of low pollution diets (without involving necessarily a cooker extruder to gelatinise the starch fraction of plant ingredients).

In commercial feeds up to 40 % dietary starch brought by cereals (Devresse, 1995) has shown beneficial when feeding shrimp with a resulting weight gain of at least 0.19g/day ; On the contrary, a pelleted feed poorly utilised, and the shrimp may have to process a greater quantity of food in order to extract the required nutrients (Smith *et al.*, 1985). Feces-forming is commonly expressed when a shrimp is fed on mussel flesh and do not produce any detectable feces, which in fact is not fully true because there is still a formation of a peritrophic membrane, so thin that it can be barely seen lying on the bottom of an experimental tank.

In terms of feed utilisation to select one ingredient versus another or how to formulate a diet based upon digestive values instead of crude values will help the nutritionist to follow regulations insisting on a restricted value for organic matter, ammonia or minerals to be released from aquaculture ponds into the environment. Even if many more data need to be obtained, results bring valuable input in terms of (i) methodology (ii) analytical procedure (iii) range of ADC values for some common shrimp ingredients.

1.1.3. Comparison between a regular grower diet and a low pollution diet

1.1.3.1. Objective

Two diets were prepared according to the idea that with a quality fishmeal meaning a high ADC and low temperature processing (Cuzon *et al.*, 1997), one can figure out that the protein utilisation will be improved and the wastes diminished. A comparison was carried out between a regular grower feed and another formulation in which the ingredients were selected according to a relatively high (> 90 %) digestive coefficient. Whether the growth of *P. stylirostris* juveniles would be influenced or not by this change was a prerequisite before being able to show any waste reduction in larger outdoor tanks.

1.1.3.2. Material and Methods

A series of tanks with 72 litres capacity were allocated to the experiment and organised in a block design system. *P. stylirostris* shrimp were harvested from a 1000 square meter earthen pond with a cast net. Animals weighing 6-7 g at start were left a few day before being dispatched by random among the different tanks. The experimental feeds were prepared at the COP workshop with a meat mincer through dies of 2 mm and dried in a fluid bed dryer during half hour at a temperature of 70° C. A semi industrial feed coming from a local feed mill equipped with a CPM Masters 50 HP was set as a control. The formulation and proximate analysis of the two diets are detailed in **table 5**.

Table 5. Composition of the two practical diets A: regular grower diet ; B = low pollution diet prepared under laboratory conditions (cold extrusion). (1) megapremix is a mixture of fishmeal (2/3) and yeast (1/3).

	A	B
fishmeal US	20.00	-
Chilean Fishmeal	-	40.00
Chilean shrimpmeal	16.00	10.00
soyabean meal	-	10.00
wheat gluten	6.55	2.50
Megapremix(1)	29.00	-
Ground wheat	20.87	30.00
soy lecithin	0.50	0.50
fish oil	3.00	3.00
Rovimix 1730(vit.)	1.00	2.00
Choline chloride	0.30	-
$NaHPO_4/KHPO_4$ 1:1	2.00	2.00
$CuSO_4$	0.03	-
protein % (Nx6.25)	46.3	43
carbohydrates % dm	15	20.2
lipid % dry matter	8.1	5.7
DE(MJ/Kg dm)	11	13
DP(g/MJ)	19	24
L-lysine	2.8	2.7
water stability % dm/hour	5.4	5.2

The main characteristics of the low pollution diet (diet B) are based on (i) a good quality fishmeal, (ii) an amount of soybean meal at the expense of fishmeal and (iii) a reduction of shrimp meal ; all the rest being more or less equal with the regular feed (A). Plant protein, basically soybean meal has been incorporated in the low pollution diet due to its digestibility (above 85 %) and wheat represents a significant increase in the formula for the same reason ; the carbohydrate content of wheat (60 %) has been shown to be digested at a fair level (90 %) even if it is a raw starch. Such modifications proceed from the knowledge on ingredients sources and their potency achieved through routine growth trials. It represents an excellent opportunity to provide cheap energy source to shrimp and a possible way to spare protein.

The feeding schedule is made according to a (Garen and Aquacop, 1992) indicating the daily percentage of feed to be distributed according to the biomass. Observations made daily consisted of mortality count, exuviae count, and estimation of left-overs. Water characteristics were similar to the description made in the first section of this report. Parameters which were followed led to estimate on growth rate, moult frequency, survival rate and protein utilisation (carcass analysis were performed on freeze-dried animals at start and end of the trial: including moisture content, protein content (Nx6.25), lipids, ash and energy (with a semi-calorimeter PARR, 1425) following methods of AOAC (1990). Growth data were analysed using analysis of variance and Duncan's multiple range test (Statistica, 1984).

1.1.3.3. Results

- Food consumption
  Food consumption of the two diet is presented in **figure 2**:

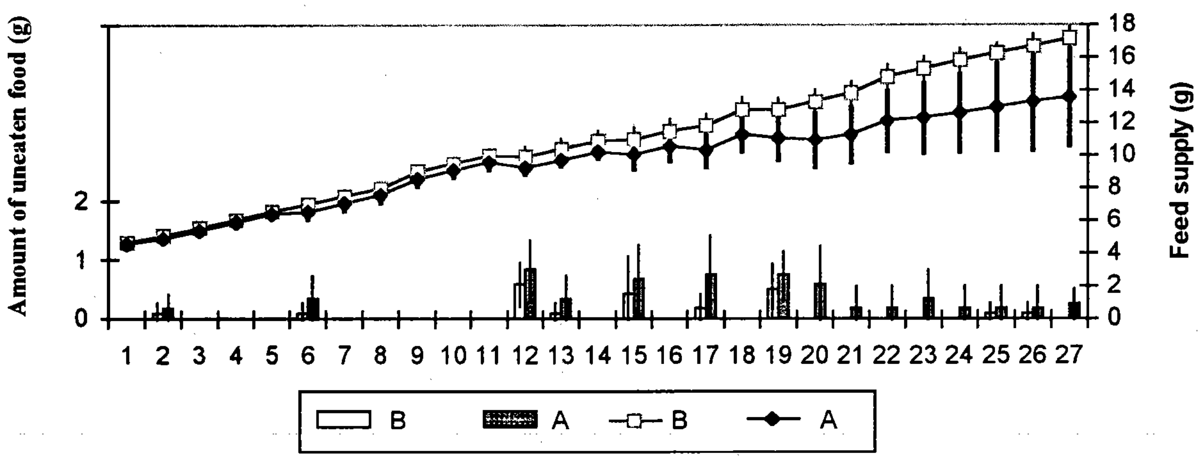


Figure 2. Evolution of feed inputs and amount of uneaten pellets during the course of experiment given by each diet in terms of mean +/- standard deviation.

Shrimp juveniles have exhibited all along the trial a steady feed intake when receiving the low pollution diet (B) ; on the contrary, the regular diet (A) was little by little showing left overs which induced a progressive reduction of daily ration in order to remain near the *ad libitum* value as defined initially ; digestible protein and digestible energy intake are similar on both feeds, utilisation of protein and energy is better with the low pollution diet (B) than with the regular feed (**table 6**).

- Mortality and moulting survey during the feeding trial.
  Mortality and moulting variation during the course of the experiment are presented in **figure 3**.

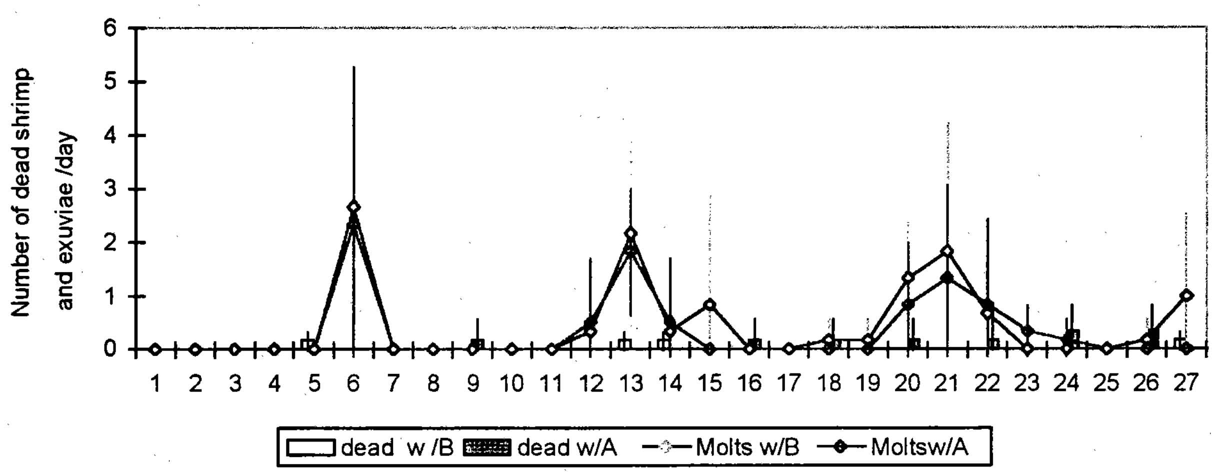


Figure 3. Mortality and moult variations during the course of experiment run on the two diets (mean +/- standard deviation).

Mortality and moulting during the course of the experiment are given below for each diet. The peak of mortality is concomitant with the peak of exuviation, emphasising the cannibalistic tendency of this species during exuviation. It is difficult to refrain cannibalism during trials where feed is provided in 2 times during the day which means that from 20.00 to 07.30 animals could suffer a lack of feed supply and cannibalism can take place.

It is clearly shown that a synchronism is achieved among individuals which renders the accuracy in terms of comparative growth rate better than a situation where all shrimp would moult at random. The intermoult cycle is found to be 6-7 days.

- Growth - utilisation of protein and energy
  Growth and protein and energy utilisation testing the two diets are presented in (**table 6**).

Table 6. Indices of feed intake, protein and energy utilisation and growth of *P. stylirostris* juveniles when fed on diet A or B. The letter *p* represents the level of significance ($p < 0.05$).

	A	B	*p*	
TCR (%)	66.5 ± 6.9	89.5 ± 10.3	0.004 *	Relative growth rate
TEA (%)	24.9 ± 3.5	28.0 ± 5.0	0.247 ns	Feed efficiency ratio
PDI (g/g)	0.68 ±0.0 7	0.70 ±0.08	0.421 ns	Digestible protein intake
EDI (kJ/g)	21.1 ± 2.5	21.5 ± 2.2	0.742 ns	Digestible energy intake
CEPD (mg/g)	0.9 ±0.2	0.7 ±0.1	0.116 ns	Digestible protein efficiency ratio (PER)
CEED (mg/kJ)	2.4 ± 0.3	2.9 ± 0.5	0.069 ns	Digestible energy efficiency ratio
CUP (%)	42.0 ± 6.4	45.0 ± 8.4	0.494 ns	Digestible protein utilisation
CUE (%)	25.9 ± 3.9	32.2 ± 6.2	0.072 ns	Digestible energy utilisation

Growth rate (TCR) is improved with the low pollution diet ($p<0.05$). Indices for feed efficiency, PER and nutrients utilisation show a trend to improve when the low pollution diet is concerned. The coefficients for energy efficiency (CEED) and digestible energy utilisation (CUE), and protein utilisation (CUP) are also improved but at a lesser extent.

1.1.3.4. Discussion

**** Feed composition***

Diet B is slightly less dense in fish meal (FM) than diet A due to the partial replacement of FM by soybean meal which confers another attribute for a low pollution status of diet B and the lysine content is not affected by such a change (**table 5**). Plant protein, basically soybean meal has been incorporated into the low pollution diet due to its digestibility (above 85 %) and wheat represents a significant increase in the formula for the same reason. The carbohydrate content of wheat (60 %) has been shown to be digested at a fair level (90 %) even if it is a raw starch. It represents an excellent opportunity to provide cheap energy source to shrimp and a possible way to spare protein.

** Feed consumption*

One can consider that feed intake is dependent on the energy content of the feed. This is probably true with shrimp. Moreover, pellet appetibility can speed up ingestion rate. The feed is quickly unpalatable because substances such as attractants have gone (Lim and Cuzon, 1994). According to the profile of those two experimental diets, it is hard to say that a real difference in terms of appetibility would exist except after day 12th on diet A (**fig 2**). Consequently the difference in ingestion rate could be due to a better protein / energy balance of one diet versus the other or a better nutritionally balanced diet in terms of amino acids profile. The composition of the low pollution diet tends to meet the requirements of the juveniles in a better way than the regular diet.

** Growth*

Growth is characterised by moulting which occurred according to a good synchronism as seen in **figure 3** and such an evolution is unusual but it brings more fineness of interpretation because growth is a consequence of 4 intermoult periods. Indices which are calculated in **table 6** are similar to previous study (Cousin, 1995): relative growth rate at 70-90 % is comparable to 60-108 % obtained with a DP/DE ratio around 20 with animals weighing 6-7g initial weight.

** Protein utilisation*

Concerning the utilisation of nutrients, CUP coefficient is similar to the values obtained in *P. stylirostris* (25-30 %) with semi-purified diets (Cousin, 1995) but above the values on *P. monodon* with 17-19 % (Sarac *et al.*, 1993). If 20-40 % protein is retained, the rest is to be used in chitin synthesis or excreted through the gills. Postprandial ammonia production is increased at higher dietary protein level (Regnault, 1981 ; Gauquelin, 1996) and values of 0.4mg $N\text{-}NH_4$/mg dry matter shrimp are recorded. Protein utilisation is 40 % in consequence, for maximum growth, one can consider that shrimp take advantage of a high dietary protein intake leading to an active catabolism of amino acids (aas). The more dietary protein, the more aas are susceptible to reach the tissue and catabolism increases. The animals can get enough essential aa concentration in the pool of aa for protein synthesis.

A feed with high quality fishmeal (good digestibility, low temperature during drying,...) and a adequate balance between protein and energy sources (DP/DE= 19) is adequate for *P. stylirostris*. The portion of energy retained is around 25 % as observed for *P. stylirostris. or P. vannamei* (Cousin, 1995) and it is lower than protein retention at the difference with data from rainbow trout (Brauge, 1994). It is important to know at animal level how the feed is metabolised Gross energy intake taken into account (GE) set at 100, the digestible energy (DE) is found at 67-82 %, the metabolisable energy (ME) obtained after ammonia excretion measurement is around 63-72 % and the net energy (NE) calculated from heat increment (HiE) assessment with O_2 consumption lead to a final value of 20 % (Teshima, 1995) for *P. japonicus*, similar to the CUE values obtained for P.stylirostris (25-32 %), compared to 30 % with salmonids where a major part of energy is coming from lipids and protein. Shrimp will derive energy from carbohydrates and protein primarily. The sparing effect of starch is more probable with *P. stylirostris* (Baillet *et al.*, 1997).

In conclusion, the comparison of feed efficiency ratios of the two diets A (regular diet) and B (low pollution diet), respectively 24.9 % and 28 %, and of their relative protein fraction (46.3 % and 43 %) has allowed determining the amounts of nitrogen potentially rejected into the environment either under shrimp faeces form or under unconsumed pellets. In the more favorable case (higher feed efficiency and lower protein rate), using **diet B has entailed a decrease of about 20 % in nitrogen waste discharged**.

1.1.4. Synthesis

At this stage of the study, a methodology was established in an efficient way to produce results at laboratory levels such as digestibility and to address more accurately the incidence of protein and energy on growth of shrimp. The data generated by the study should bring more information to control metabolic wastage by animals being raised under intensive or semi-intensive conditions.

The experiments carried-out at animal level have permitted to measure the Apparent Digestible Coefficient (ADC) for selected nutrients and hence the formulation of highly digestible feed pellets. These result are a significant advance in this domain where, due to the difficulty of performing this type of experiment on shrimps, large knowledge gaps remain unbridged.

This study has also shown that a feed pellet less rich in proteins than a regular diet (43 % and 46 % respectively) but presenting a higher ADC may bring increased relative growth rate (89,5 and 66,5 % respectivelly) and feed efficiency (28 % and 24,9 %).

The evaluation of pollution level of the two tested diets in term of nitrogen waste demonstrate that for a same growth performance, up to 20 % decrease in nitrogen waste can be obtain with a improed diet diet compared to a regular one.

The research work is still at its early stage in terms of evaluation of wastage produced at the animal level. The preliminary results need further validation through additional experiments both *in vitro* and *in situ* to achieve a real improvement in the diet, while keeping production costs in line with economic constraints.

1.1.5. References

Akiyama D.M., Coelho S.R., Lawrence, A.L. et Robinson, E.H., 1989. Apparent digestibility of feedstuffs by the marine shrimp P.vannamei Boone. Nippon Suisan Gakkaishi, 55: 91-98.

Aquacop *et al.*, 1995. Determination of ADC for peneid shrimp according to a revised system. Oral pesentation WAS, San Diego, Feb. 1995.

Association of Official Analytical Chemists, 1990. Method of analysis, AOAC, Washington, D.C., USA.

Atkinson J.L., Hilton J.W., and S.J.Slinger, 1984. Evaluation of acid-insoluble ash as an indicator of feed digestibility in RT (Salmo gairdneri. Can. J. Fish. Aquat. Sci., 41.

Baillet C, G.Cuzon, M.Cousin and C.Kerleguer, 1997. Effect of dietary proetin levels on growth of P.stylirostris .Aquaculture Nutrition, 3: 49-53.

Brauge C, Medale, F. et Corraze G., 1994. Effect of dietary carbohydrate levels on growth, body composition and glycaemia in RT reared in seawater. Aquaculture, 123: 109-120.

Brunson J.F., Romaire R.P. and R.C.Reigh, 1997. Apparent digestibility of selected ingredients in diets for white shrimp Penaeus setiferus. Aquaculture Nutrition, 3: 9-16.

Cho C.Y., Slinger S.J. and H.S. Bayley, 1982. Bioenergetics of salmonid fishes: energy intake, expenditure and productivity. Comp. Biochem. Physiol. vol. 73B, 1: 25-41.

Cho C.Y., Hynes H.D., Wood K.R. and H.K. Yoshida, 1991. Quantiation of fish culture wastes by biological (nutritional) and chemical (limnological) methods ; the development of high nutrient dense (HND) diets. IN Nutritional strategies and Aquaculture wastes, C.B. Cowey and C.Y. Cho (editors), pp 37-50.

Cho C.Y. and Bureau, D.P., 1997. Reduction of wastes output from salmonid aquaculture through feeds and feeding. The Progressive Fish Culturist, 59: 155-160.

Cousin M., 1995. Etude de l'utilisation des glucides et du rapport proteines-énergie chez deux espèces de crevettes pénéides, *P. vannamei* et *P. stylirostris.*, 210 pp.

Cousin M., G. Cuzon, J.Guillaume and Aquacop.1995. Digestibility of starch in P.vannamei in vivo and in vitro on 8 samples of various origins. Aquaculture.

Cruz E, D. Ricque, G. Cuzon and I. Pike, 1996. Criteria for selection of fishmeals to be incorporated in shrimp feeds. Aquaculture Nutrition (submitted).

Cuzon G., Pike I., Cousin M. and Aquacop. 1997. Comparison of fishmeal quality on growth response with 3 species, *P. monodon, P. stylirostris and P. vannamei.* Paper from a STD report on Fishmeal potential for shrimp feeds (submitted).

Deering, *et al.*, 1996. Effects of temperature on growth and protein assimilation on juvenile leader *Penaeus monodon.* Oceanic Litterature Review, 43 (7).

Devresse B., 1995. Evaluation of several commercial shrimp feeds. In Feed Ingredients in Asia. 20 pp.

Faucon M., 1997. Croissance et métabolisme chez la crevette en microcosme. Application à la mise au point d'aliments moins polluants. Rapport de vatariat Ifremer, 20pp.

Garen P. and Aquacop, 1992. Nuevos resultados en la cria intensiva de camaron *P.vannamei* y *P.stylirostris.* Communication au Congres d'aquaculture de Guayaquil, Equateur, nov. 1992.

Gauquelin F., 1996. Etude de l'excretion azotée et de l'influence du régime alimentaire chez *P. stylirostris.* Rapport de stage Ifremer/COP, 35 pp.

Lim C. and G.Cuzon, 1994. Water stability of shrimp pellet, a review. Asian Fisheries Science, 7: 115-127.

Maynard L.A. and J.K. Loosli. 1969. Animal nutrition, *6th ed. Mc Graw-Hill, NY, St Louis, San Francisco, London, Sydney, Toronto, Mexico, Panama*, 613 pp.

Metailler R., 1994. Nutrition des poissons et environnement aquatique: digestibilité, excrétion. La pisciculture française, 117: 18-23.

Nedelec G. Cuzon G., Faucon M. and Aquacop. 1996. Range of variation for aquafeeds at small scale in relation to growth and reproduction performances. Poster WAS, march, 1996.

Regnault M., 1981. Influence à long terme du taux protéique sur l'excrétion d'azote et le métabolisme de la crevette *C. crangon L.*.

Sarac H.Z. *et al.*, 1993. Observations on the chemical composition of some commercial prawn foods and associated growth responses in P.monodon. Aquaculture, 115: 97-110.

Shiau S.Y. and Chou B.S., 1991. Effects of dietary protien and energy on growth performance of tiger shrimp P.monodon reared in seawater. Nippon Suisan Gakkaishi, 57: 2271-2276.

Smith L.L., Lee P.G., Lawrence A.L. et Strawn K., 1985. Growth and digestibility by 3 sizes of P.vannamei Boone: effects of dietary protein level and protein source. Aquaculture, 46: 85-96.

Statistica, 1984. Software for statistical analysis.

Teshima S. and A. Kanazawa, 1983. Digestibility of dietary lipids in the prawn. Bull. Jap. Soc. Sci. Fish., 49: 963-966.

Teshima S., 1995. Personal communication.

1.2. Research conducted at pond level

Authors: Intensive condition: (Tahiti)	*P. Garen*	*Ifremer/Tahiti*
	J.L. M.Martin	*Crema-L'Houmeau*
Authors: Semi-intensive conditions: (New-Caledonia)	*J.L. M.Martin*	*Crema-L'Houmeau*
	H. Lemonnier	*Ifremer/New-Caledonia*
	Y. Veran	*Ifremer/New-Caledonia*

1.2.1. Introduction

We have previously noticed that two main limiting factors in successful shrimp farming are identified as (i) intensification, in terms of stocking densities or loaded biomass, and (ii) an inadequate water quality management of ponds (Hirono, 1992 ; Chien, 1992). An inadequate management of both parameters leads to an increase in waste formation and to an accumulation of that wastes in the ponds and in the surrounding environment.

Concerning the influence of stocking density on wastes formation, many works show an inverse relationship between the growth of shrimp and stocking density (Ray and Chien, 1992 ; Lee *et al.*, 1986 ; Daniels *et al.*, 1995 ; Sandifer *et al.*, 1987). This has for consequences to increase the Food Conversion Ratio (FCR), and, then, the quantity of wastes produced per kg of reared shrimp. These wastes, mainly feces and unconsummated feed pellets, first settle in the sediment. As a consequence organic wastes and metabolites of degraded organic matter accumulate in the sediment of ponds (Boyd, 1992 ; Fast and Boyd, 1992 ; Hopkins *et al.*, 1994), with well known consequences such as increasing concentrations of metabolites

(N-NH3-4, N-NO2⁻-3 for example), and deficiency in oxygen concentrations during the night period. Part or totality of the waste is flushed out of the ponds, immediately or later after the organic matter has been degraded. The discharge of wastes from the ponds to the environment will be dependant upon the rate of water exchange. Control of parameters such as dissolved oxygen, suspended solids and algal blooms in the water column is vital to proper management of shrimp pond water (Wang, 1990), and water exchange is one of the major methods of maintaining good water quality (Allan *et al.*, 1993). As a matter of fact, water exchange is used in semi-intensive and intensive shrimp farming to compensate for evaporation losses or excessive rainfall by mixing up pond waters to acceptable levels of salinity. It also minimises diurnal fluxes in dissolved oxygen, eliminates organic matter and toxic metabolites that can be harmful to shrimp and prevents excessive algal blooms (Chamberlain, 1987 ; Boyd, 1990 ; Hopkins *et al.*, 1993 ; 1995 ; Martinez-Cordova, 1995). Nevertheless, discharge from water exchange in shrimp farming can be substantial as production of one metric ton of shrimp typically uses 55 000 to 86 000 tons of water (Hopkins and Villalón, 1992). Some recent studies have demonstrated that water exchange can be significantly reduced without affecting shrimp production (Browdy *et al.*, 1993 ; Hopkins *et al.*, 1991 ; 1993 ; Allan and Maguire, 1993 ; Martinez-Cordova, 1995 ; Goxe, 1988).

As a consequence of the influence of stocking density and water renewal on wastes discharge in the surrounding environment, the new tendency is to farm shrimp with decreasing stocking density and water exchange rates. Many authors have studied waste formation and pond management (Wang, 1990 ; Hopkins *et al.*, 1993 ; 1994), including water and sediment in shrimp ponds (Hunter *et al.*, 1987 ; Chen *et al.*, 1990a ; Boyd, 1992 ; Ray and Chien, 1992 ; Funge-Smith, 1993 ; Tunvilai *et al.*, 1993a ; 1993b ; Boyd *et al.*, 1994). It is to be noticed that studies on the dynamic and quantification of waste flows and budget in marine shrimp ponds are few. One report is that of Briggs and Funge-Smith (1994) in commercially operated marine shrimp ponds in Thailand. Because of that, the parameters considered in our study (stocking density and water renewal rate) could not be taken into account as a variable in these author's study. So, the relationship between the dynamic and quantification of waste discharge on the one hand and stocking density and water renewal rate on the other is yet to be investigated.

Within the wide range of rearing technologies from real extensive to highly intensive a simple classification can be given in three kinds of culture: extensive, semi-intensive and intensive cultures. Fully extensive cultures do not produce waste because there is no feed input. All other types of culture produce waste. Pond and culture management rules vary a lot. Cultures carried out in earthen ponds, with stocking densities up to 40 shrimp.m^{-2}, implemented in Southeast Asia and South America are thereunder called semi-intensive. Cultures conducted in concrete ponds (Tahiti) or liner bottom ponds (Southeast Asia) at densities above 50 shrimp.m^{-2} are called intensive. These last one are performed without the influence of sediment and of waste accumulated along the successive cultures cycles, provided those waste are frequently removed. In addition stocked shrimp biomass, water exchange rates and needs for supplemental aeration will change from a culture to another. Varying characteristics of pond bottom, various rearing densities, pond culture management rules (aeration, water exchange) will make differences in the « metabolism » of organic matter (feces, non ingested feed pellets...) non assimilated by shrimp, therefore in the metabolism of waste from a culture to another. So, in order to determine the nature and the quantification of wastes, both semi intensive rearing in earthen ponds and intensive rearing in concrete ponds will be investigated in this study.

This part of report aims to establish a waste budget for extensive to intensive rearing of *Penaeus stylirostris*, and to determine the relationship between, on the one hand, stocking density and water renewal and, on the other hand, (i) growth of shrimp and production, (ii) quantity, characteristics and fate of wastes produced by rearing activities. At last, because the necessity arose, in order to establish the budget of waste, the influence of stocking density and of water renewal on sediment characteristics, in relation to waste accumulation, was also studied.

1.2.2. Methodology, material and methods

In this section we give the information's concerning these topics, which are shared by all experiments.

Calculation of waste budget. In order to establish the formation of wastes, and to be able to quantify them, it was necessary to consider a tracer able to quantify the input and output of the organic matter, under its different forms: solid and particulate (feed pellets, shrimp, particulate suspended matter in the water), or dissolved (metabolites of degradation, mineral and organic). In this study we have considered that nitrogen could represent, through its different forms, 100 % of the organic matter entering in the ponds and of the waste discharged from the pond. So, the budget of waste will be established through the budget of nitrogen. The method of calculation of this budget is given later in the section of the report related to that topic.

The experiments: which species, where, how ?

The experiments were carried out with *Penaeus stylirostris* which is the species reared in Pacific Island. They were performed in two sites located in French Territories in the Pacific Ocean: in New Caledonia for experiments concerning from extensive to semi-intensive rearing, and in Tahiti for intensive rearing. In New Caledonia the ponds are earthen ponds while in Tahiti they are concrete ponds.

In New Caledonia, the experiment were carried out at the Aquaculture Experimental Station of Saint-Vincent. Six rectangular earthen ponds were used with a surface area ranging from 1370 to 1520 m^2 (see **figure 4**). Water was pumped directly from the sea (Bay of Saint-Vincent) to the culture ponds through a short distribution canal. Flow rate for each pond was measured with a Mebflügel Meter (Type C2"10.150"). Water exchange rate was calculated by timing the duration of the renewal flow for each pond.

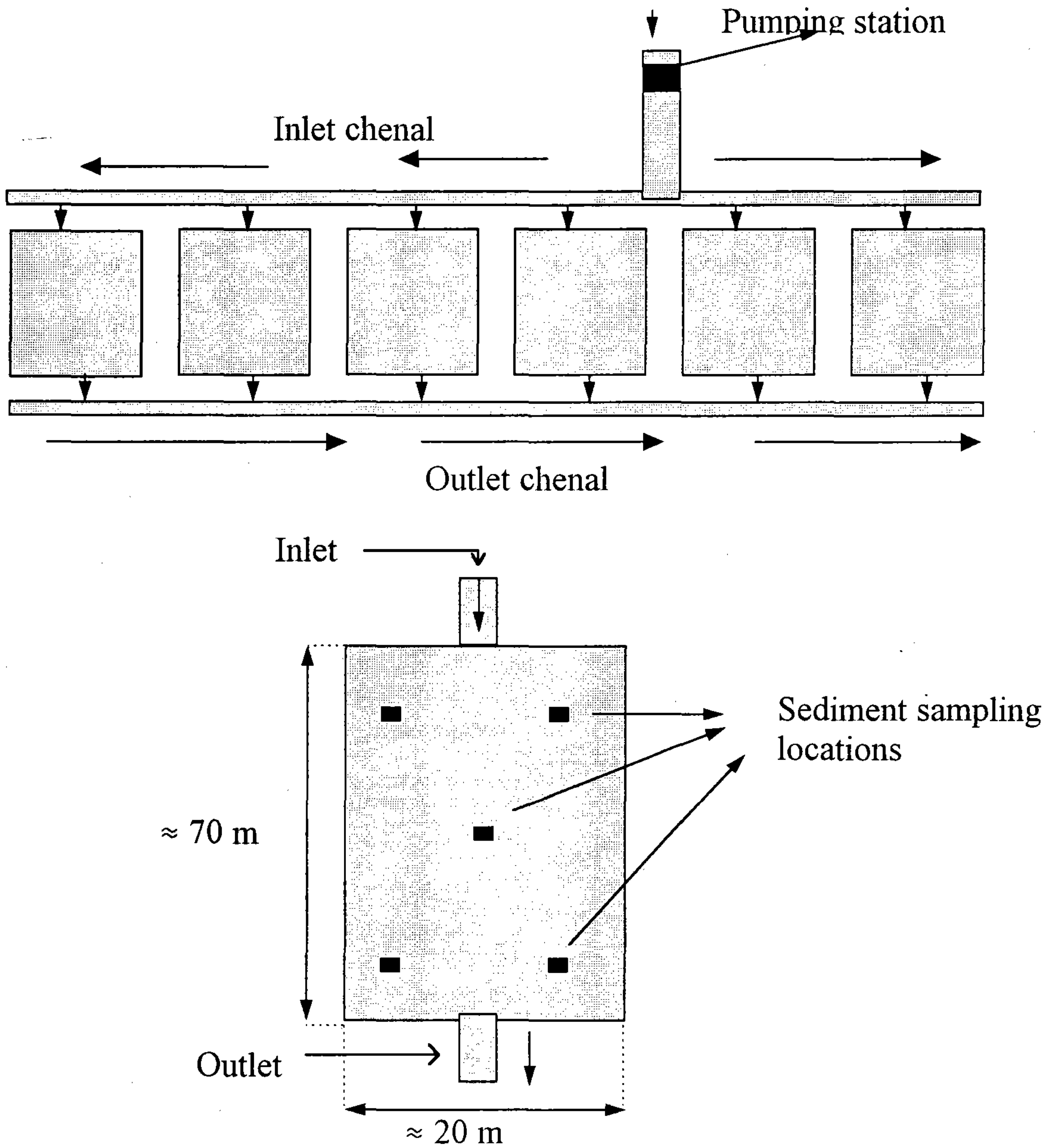


Figure 4. Scheme of the earthen ponds where experiments on semi-intensive rearing have been carried out.

In Tahiti, ponds of 13 m² have been used. They are rectangular, with concrete walls and bottoms, and equipped with central water drainage. The discharge of the water out of the pond is made through a surface overflow pipe. Each pond is equipped with 2 airlifts (see **figure 5**).

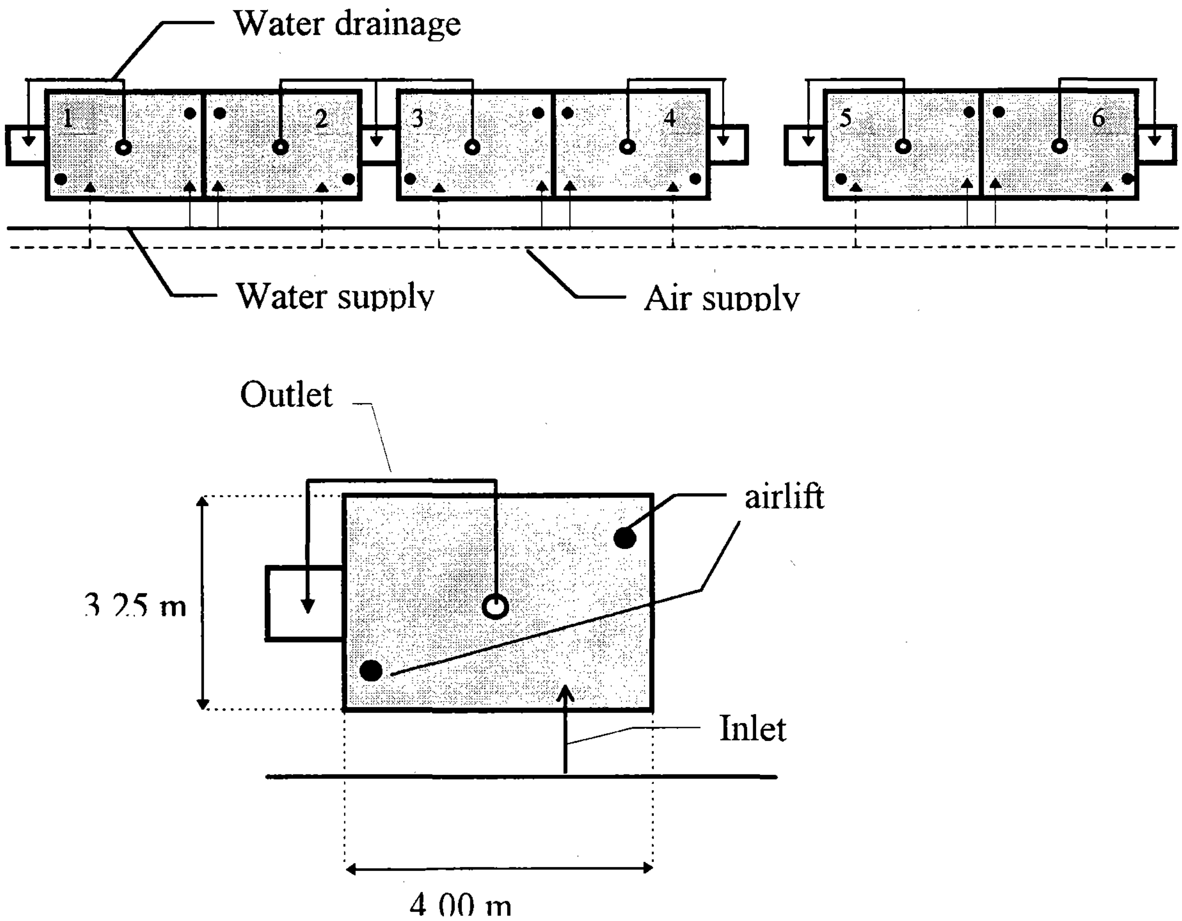


Figure 5. Scheme of the concrete ponds where experiments on intensive rearing have been carried out.

In both cases, New Caledonia and Tahiti, the water renewal is made by means of a pumping station, allowing to control the flow and volume of the water during the exchange.

The specific characteristics of each experiment (stocking densities, water renewal rate, frequency of sampling...) are given in the relevant section.

The analyses of parameters

Analyses of nitrogenous nutrients and soluble organic nitrogen were carried out after filtering water samples through GF/C Whatman filters. The colorimetric methods - automatic autoanalyser with continuous flow (Treger and Le Corre, 1975) - were used according to the methods of Benschneider and Robinson (1952) for (NO_3^-)-N, Wood *et al.* (1967) for $(NO_3^- + NO_2^-)$-N, and Koroleff (1983) for $(NH_4^+ + NH_3)$-N. Analyses of soluble organic nitrogen were carried out after oxidation of the total soluble nitrogen by exposing the samples to a 1500 W quartz lamp during 2,5 hours (Armstrong and Tibbits, 1968). Soluble organic nitrogen is expressed as the difference between total soluble nitrogen and soluble mineral nitrogen [(NO_3^- +NO_2^-)-N + (NH_4^++NH_3)-N].

Suspended solids were collected on pre-washed, dried, and weighed GF/C filters and measured for total particulate matter (drying at 60° C during 24h). The concentration of particulate organic matter was determined by ignition of the filtered total particulate matter at 450° C for 4 hours. Total particulate nitrogen concentration was determined, after the samples were filtered through GF/C Whatman filter, using a gaz-chromatograph carbon/nitrogen analyser (Carlo Erba 1500) according to the method of Hedges and Stern (1984). Concentrations of chlorophyll-a and pheopigments were determined, after samples were filtered through GF/C Whatman filters, according to the method of Holm-Hansen and Riemann (1978). The pigments were extracted with methanol and concentrations determined with a fluorimeter at 665 nm, before and after acidification.

Dissolved Oxygen (DO) and water temperature were recorded in all ponds at half-depth twice daily: (6:00 am) and (4:00 pm) with a portable Otterbine Sentry III oxygen meter. Salinity was measured using an Aquafauna refractometer (ABMTC) and pH with a pH-meter Knick 651 twice a week (Monday and Thursday) in the evening (4:00 PM).

Sediment samples were centrifuged (2000 G for 30 minutes) and nitrogenous nutrients in pore water were analysed as previously described for water samples. Analyses of nitrogen in sediment, in feed pellets and in shrimp were carried out with the same technique used for nitrogen in suspended solids. The samples were previously dried (24h at 60° C) ground and homogenised. Twenty ml of each sediment sample was weighted to determine the density and dried at 60° C during 5 days to calculate water content. The concentration of organic matter was determined by ignition of the dry sediment at 450° C for 5 hours.

1.2.3. Results

1.2.3.1. <u>Effects of stocking density on wastes discharge</u>

1.2.3.1.1. For extensive to semi intensive rearing

1.2.3.1.1.1. Specific characteristics of this experiment

Experiments were carried out in New Caledonia in earthen ponds. Six rectangular ponds (size 1370 to 1520 m^2, water depth 1.3 m) were used. Water was changed every morning. During the rearing period (183 days) 10 % of pond volume was changed every day. This equates to 130 $l.m^{-2}$ d^{-1}. No mechanical aeration was used during the rearing. Prior to use, the ponds were dried for 63 days and aerated several times with a scarifier. In order to measure accumulation of particles and wastes, and/or pond erosion, five iron rods with graduated marks, were driven into the corner and at the centre (see **figure 4**), smoothened and flattened, of each pond, before the beginning of the rearing cycle. Samplings of sediment were carried out in these five areas.

The ponds were seeded with juvenile shrimp (PL 17) at 1, 4, 7, 15, 22, and 30 $shrimp.m^{-2}$. Feeding was 4 times a day with pellets commonly used in New Caledonia. Feed consumption was checked 1 hour after distribution, in immersed trays, to adjust the daily ration as close as possible to actual requirements. Stock was sampled twice a month to determine size.

Water sampling and measurements were carried out once a week. Water was sampled at dawn (6 a.m.), just before water change, at 50 cm depth, in the inlet channel for inflow and near the outlet of each pond for outflow.

At the end of the experiment, ponds were drained and shrimp harvested in a net bag over the outlet pipe. The whole crop of each pond was weighted *en masse*. Survival, mean individual weight , total biomass gain were calculated for each pond. The total quantity of food added to each pond was used as an estimate of food consumption. Food conversion ratio (FCR) for each crop was estimated.

1.2.3.1.1.2. Results

Shrimp weight and survival rate at harvest appeared to be inversely proportional to stocking density (**table** 7). Mean shrimp weight ranged from 16.8±2.4 g to 39.2±4.3 g. Survival rate ranged from 92.1 % to 38.3 %. As a matter of fact, an inverse correlation exists between initial stocking density on the one hand and survival rate ($p<0.0005$, $r = 0.953$), and final weight ($P< 0.02$, $r = 0.844$) on the other hand. A positive correlation exists between initial stocking density and the food conversion ratio ($p<0.01$, $r = 0.938$), and .the quantity of wastes generated per kg reared shrimp($p<0.01$, $r = 0.930$).

Table 7. Characteristics of stocking parameters and rearing results in the different experimental earthen ponds.

Stocking density	Surface of pond (m^2)	Final biomass (kg)	Final weight (g ± S.E.)	Survival rate (%)	Total feed in pond (kg)	F.C.R.[a]
1	1370	39.8	39.2 ± 4.3	92.1	53.3	1.34
4	1520	142.5	27.6 ± 3.2	93.8	219.8	1.54
7	1450	244.5	24.5 ± 2.6	83.3	417.1	1.71
15	1460	346.0	19.9 ± 1.9	79.0	546.5	1.58
22	1450	284.1	20.3 ± 2.4	42.3	665.7	2.34
30	1500	288.7	16.8 ± 2.4	38.3	786.6	2.73

The final weight of shrimp is expressed as the mean of 15 shrimp ± standard deviation.
[a] FCR = Food Conversion Ratio.

Table 8 shows the concentration of particulate and dissolved elements and compounds in inflow and outflow during the rearing period. The concentration of oxygen is also shown. The values shown do not take into account change over the course of the rearing cycle, which was outside the scope of this project.

Table 8. Concentration of seston and dissolved elements and compounds in inflow and outflow during the rearing.

	Inflow	Outflow					
Stocking density		1	4	7	15	22	30
Particulate							
Seston ($mg.l^{-1}$)	36.1±12.3	33.2±13.3	34.7±14.2	36.5±16.9	34.2±12.8	35.8±15.7	36.3±11.5
Org. Mat. ($mg.l^{-1}$)	8.9±4.2	9.6±4.1	10.8±4.1	11.2±4.6	10.0±3.9	10.9±4.3	11.5±4.1
Org. Mat. (%)	24.9±9.4	29.9±9.4	32.0±5.6	31.9±7.9	29.5±4.9	31.3±6.6	31.7±8.3
Chl-a ($\mu g.l^{-1}$)[a]	2.9±3.7	7.1±3.9	9.5±4.8	13.3±7.9	10.6±7.5	15±15.5	15.3±14.7
	(0.70-16.8)	(1.7-24.7)	(2.3-24.9)	(2.2-31.9)	(2.1-29.2)	(1.9-64.8)	(0.8-52.1)
Pheop. ($\mu g.l^{-1}$)	1.5±1.9	3.1±1.7	4.8±2.4	6.4±4.2	4.7±3.7	6.1±6.1	4.7±3.8
Chl-a/seston. ($g.kg^{-1}$)	0.08	0.21	0.27	0.37	0.31	0.45	0.42
N ($mg.l^{-1}$)[a]	0.18±0.08	0.26±0.10	0.32±0.12	0.35±0.17	0.33±0.19	0.39±0.24	0.42±0.28
	(0.06-0.41)	(0.12-0.60)	(0.14-0.56)	(0.12-0.79)	(0.10-0.74)	(0.09-0.98)	(0.10-1.04)
Soluble							
(NH_4^+-NH_3)-N ($\mu g.l^{-1}$)	14.2±0.72	10.36±6.7	9.8±5.9	9.8±4.5	10.5±6.0	10.2±4.6	10.1±4.2
(NO_2^--NO_3^-)-N ($\mu g.l^{-1}$)	11.1±36.3	1.7±5.2	5.0±16.0	4.2±16.8	2.7±6.6	2.4±6.0	1.4±2.8
(organic)-N ($\mu g.l^{-1}$)	111.0±74.1	157.5±72.7	149.1±40.3	150.5±51.8	127.7±40.7	133.9±38.6	147.7±49.3
total (soluble)-N ($\mu g.l^{-1}$)[a]	131.3± 96.3	169.4±71.4	165.6±39.8	164.8±48.7	140.3±39.3	146.9±35.1	159.2±50.1
	(44-254)	(86-245)	(99-283)	(47-329)	(72-240)	(55-548)	(51-676)

Each value represents the mean of ≈ 26 analyses ± standard deviation.
[a] Between brackets are range values.

The mean values were determined in order to calculate the budget of nitrogen and of other components such as suspended solids. Attention is drawn to the following points. There is no apparent increase in the average total suspended particles concentrations in the inflow compared to that of the outflows. The mean concentration of seston in the inflow was 36.1±12.3 $mg.l^{-1}$, and at the outlet it varied from 33.2±13.3 $mg.l^{-1}$ to 36.5±16.9 $mg.l^{-1}$ depending on the pond. Nevertheless, an increase in the proportion of organic matter in the suspended solids was observed. So, for particulate nitrogen, the average concentrations increased from 0.18±0.08 $mg.l^{-1}$ to 0.42±0.28 $mg.l^{-1}$ in the inflow and at the outlet respectively, of pond with 30 $shrimp.m^{-2}$. Concentrations of chlorophyll-a in suspended particles increased from 0.08±0.03 $g.kg^{-1}$ in inflow to 0.42±0.19 $g.kg^{-1}$ at outlet of pond 30 $shrimp.m^{-2}$. The large standard deviations observed for most parameters demonstrate the existence of a strong variability of these parameters within the same pond during the rearing cycle.

Figure 6 shows, as an example, the variations of 2 parameters related to phytoplanktonic blooms and/or organic matter, chlorophyll-a and particulate nitrogen, at outlet of the ponds, during the rearing cycle. An increased concentration, from the beginning to the end of the rearing cycle can be pointed out. The highest concentrations, up to 64.8 $\mu g.l^{-1}$ of chlorophyll-a and 1.04 $mg.l^{-1}$ of particulate nitrogen, are shown essentially at the end of the rearing cycle. The increase of the concentrations of chlorophyll-a and particulate nitrogen is particularly obvious in the ponds with the highest stocking density, 22 and 30 $shrimp.m^{-2}$. The lowest increase in the concentrations of these 2 parameters is observed in pond 1 $shrimp.m^{-2}$.

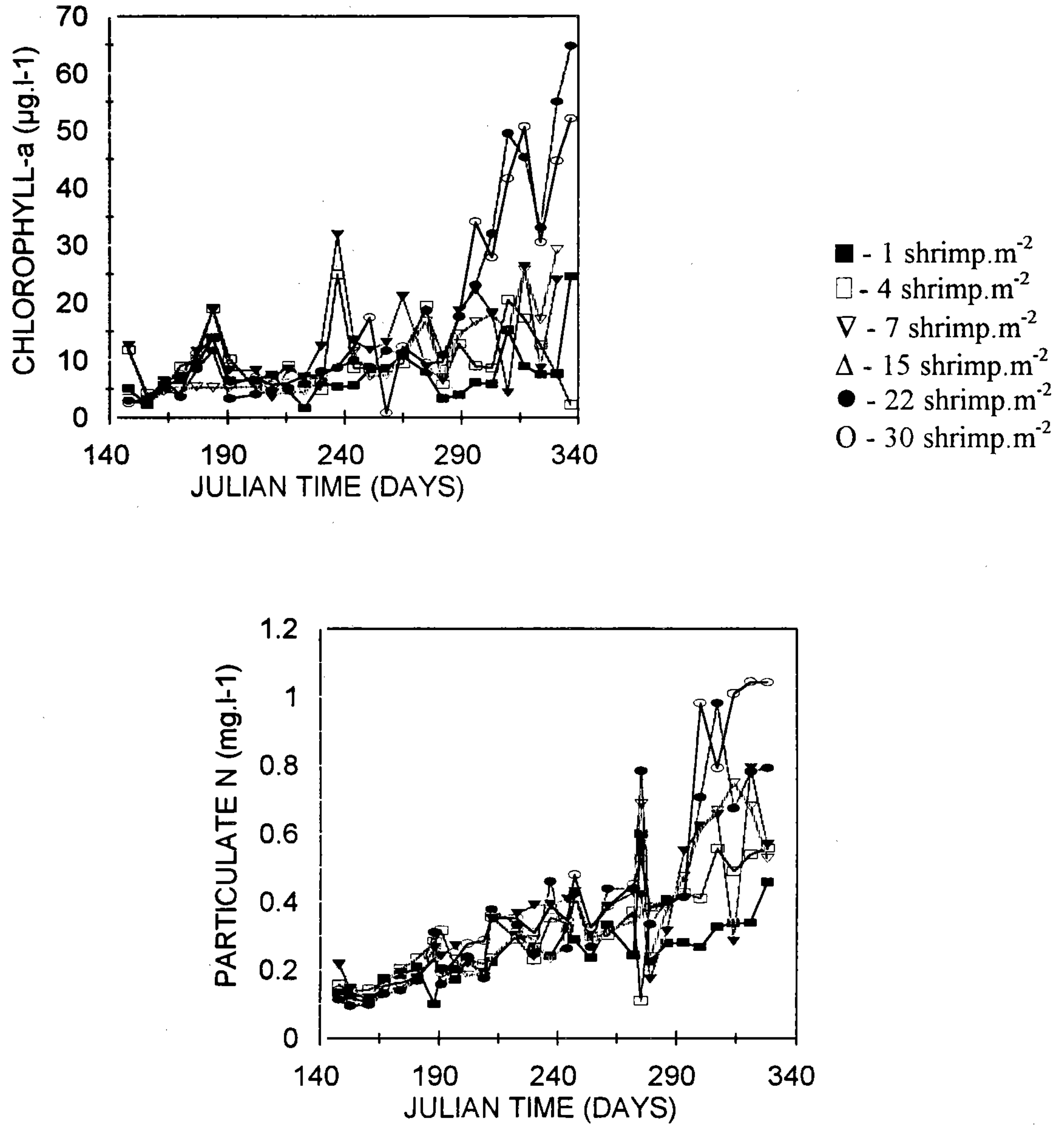


Figure 6. Variations of the concentrations of chlorophyll-a and particulate nitrogen, in the ponds, during the rearing cycle.

Concerning soluble elements and compounds in water, mean concentrations of $(NH_4^+ + NH_3)$-N decreased from 14.2±0.72 $\mu g.l^{-1}$ in the inflow to from 9.8±5.9 $\mu g.l^{-1}$ to 10.5±6.0 $g.l^{-1}$ at the outlet of ponds. Mean concentrations of $(NO_2^- + NO_3^-)$-N decreased from 11.1±36.3 $\mu g.l^{-1}$ in the inflow to 1.4±2.8 $\mu g.l^{-1}$ to 5.0±16 $\mu g.l^{-1}$ at the outlet.

Average oxygen concentration (**table 9**) decreased as rearing density increased. For measurements carried out at dawn, the mean O_2 concentrations decreased from 5.79±0.70 $mg.l^{-1}$ for a stocking density of 1 $shrimp.m^{-2}$ to 4.27±1.30 $mg.l^{-1}$ for a stocking density of 30 $shrimp.m^{-2}$. At dawn, the lowest value observed, shown at the end of the rearing cycle was 2.7 $mg.l^{-1}$ in the pond with 30 $shrimp.m^{-2}$. For measurements carried out at 4 p.m., the mean concentrations ranged from 7.69±0.52 to 8.66±0.76 in the pond with 4 $shrimp.m^{-2}$ and the pond with 30 $shrimp.m^{-2}$ respectively. The lowest differences of oxygen concentrations, measured at dusk and dawn, were observed at the beginning of the rearing cycle, while the highest took place at its end. The mean values of pH measured at 4 p.m., were relatively homogenous. They ranged from 8.12±0.14 to 8.26±0.17 in ponds 22 an 4 shrimp.m^{-2} respectively. The lowest and highest pH values measured during the rearing cycle were 7.9 and 8.5 respectively. The mean temperature was 22.9±1.97° C for morning measurements, and 25.0±2.3° C for evening measurements. The lowest and highest values were 19.5 and 30.5° C respectively. The mean salinity was 35.3±2.1. It ranged from 30 to 38 ‰.

Table 9. Variations of hydrobiological parameters in the ponds.

Stocking density	1	4	7	15	22	30
oxygen (morning) [a]	5.79±0.70 (4.5-6.7)	5.56±0.48 (4.9-5.9)	5.48±0.44 (4.8-6.2)	5.28±0.69 (4.3-6.5)	4.74±0.86 (3.9-6.4)	4.27±1.30 (2.7-6.4)
oxygen (evening) [a]	7.96±0.73 (7.2-8.6)	7.69±0.52 (7.3-8.3)	7.83±0.47 (7.0-8.4)	8.18±0.42 (7.1-8.7)	8.36±0.60. (7.2-9.4)	8.66±0.76. (7.0-9.6)
pH (evening) [a]	8.19±0.15 (7.9-8.5)	8.26±0.17 (8.0-8.5)	8.18±0.15 (7.9-8.4)	8.13±0.14 (7.9-8.3)	8.12±0.14 (7.9-8.4)	8.13±0.15 (7.9-8.3)
T° (morning) [a b]	22.90±1.97 (19.5-27.5)	-	-	-	-	-
T° (evening) [a b]	25.0±2.3 (21.0-30.5)	-	-	-	-	-
Salinity (‰) [a b]	35.3±2.1 (30-38)	-	-	-	-	-

Results are expressed as means ± standard deviations.
[a] The range is shown in brackets.
[b] Temperature and salinity measurements were made only in the pond stocked at 1 shrimp.m^{-2}.

Sediment characteristics at harvest are shown in **table 10**. The elevation of pond bottom, occurring during the rearing cycle, was measured on the 5 graduated rods driven into the bottom of each pond before the beginning of the rearing cycle. This elevation corresponds to the difference of level observed at the beginning and end of the rearing period. Each value corresponds to the mean of the 5 observations made in each pond. Elevation varied from 0.50±0.28 cm for the pond with 1 shrimp.m^{-2} to 4.54±0.73 cm for that with 30 shrimp.m^{-2}. The average concentration of organic matter increased with stocking density, from 6.35±0.36 % to 9.10±0.50 %. The concentration of total nitrogen in the sediment increased from 1.50±0.23 mg.g^{-1} to 2.04±0.31 mg.g^{-1}. The concentration of $(NH_4^+ + NH_3)$-N in pore water, increased with stocking density. It ranged from 1.25±0.37 to 6.50±0.48 mg.l^{-1} for stocking density 1 shrimp.m^{-2} and 30 shrimp.m^{-2} respectively. Total soluble-N average concentrations increased, from 5.99±1.02 mg.l^{-1} to 14.54±1.06 mg.l^{-1}, for the pond with 1 shrimp.m^{-2} to that with 30 shrimp.m^{-2}.

Table 10. Sediment characteristics at harvest. Results are expressed as means of 5 analyses ± standard deviations.

Stocking density	1	4	7	15	22	30
Accumulated layer (cm)	0.5 ± 0.28	1.02 ± 0.61	2 ± 0.65	2.5 ± 0.78	3.5 ± 0.90	4.5 ± 0.73
Organic matter (% dw)	6.35±0.36	6.49±0.26	7.47±0.19	8.34±0.53	8.87±0.68	9.10±0.50
Total nitrogen (mg.g^{-1})	1.50±0.23	1.85±0.19	1.89±0.19	1.80±0.21	2.00±0.28	2.04±0.31
Pore water (mg.l^{-1})						
$(NH_4^+ - NH_3)$-N	1.25±0.37	2.32±1.09	3.22±0.70	4.16±0.92	6.84±1.48	6.50±0.48
$(NO_2^- - NO_3^-)$-N	0.68±0.22	0.17±0.04	0.67±0.13	0.25±0.11	0.39±0.19	0.74±0.29
Organic-N	3.99±0.81	5.07±1.44	6.82±0.36	7.73±2.58	6.66±2.68	8.66±3.81
Total soluble-N	5.99±1.02	7.64±2.31	10.79±0.72	12.21±2.73	9.60±4.85	14.54±1.06

Table 11 shows the nitrogen budget. Some of the components can be calculated easily, from concentration, mass and volume. This is the case for the nitrogen input and output related to feed pellets and harvested shrimp, respectively. This is also the case for the nitrogen input in the inflow and the nitrogen output in the outflow, which were calculated as follow: total nitrogen in the inflow (or outflow) = mean concentration of total N (dissolved + particulate) in inflow (or outflow) of the pond x total volume of water exchanged, during the rearing cycle.

Table 11. Nitrogen budget in the ponds[a].

Stocking density	**1**	**4**	**7**	**15**	**22**	**30**
A Pond surface (m^2)	1370	1520	1450	1460	1450	1520
B Harvest (kg wet weight)	39.8	142.5	244.5	346	284.1	288.7
C feed pellets-N ($kg.pond^{-1}$)	3.7	15.3	30	37.9	46.3	54.7
D shrimp harvested-N ($kg.pond^{-1}$)	1.28	4.60	7.89	11.15	9.17	9.32
E feed efficiency-N (%)	34.6	30.1	26.3	29.4	19.8	17.0
F total waste-N ($kg.pond^{-1}$)	2.42	10.7	22.1	26.75	37.13	45.38
G waste-N ($g.kg^{-1}$ shrimp harvested)	60.8	75.1	90.4	77.3	130.7	157.2
H total waste-N ($g.m^{-2}$)	1.8	7.0	15.2	18.3	25.6	30.3
I waste in outflow water-N ($g.m^{-2}$)	2.0	3.4	4.2	3.7	5.1	5.9
J waste-N in sedim.+atmos. ($g.m^{-2}$)	-0.2	3.6	11	14.6	20.5	24.4
INPUT-N ($g.m^{-2}$)						
K water-N (dissolved + particulate)[b]	4.4 (62.0)	4.4 (30.3)	4.4 (17.5)	4.4 (14.5)	4.4 (12.1)	4.4 (10.8)
L feed pellets-N[b]	2.7 (38.0)	10.1 (69.7)	20.7 (82.5)	26.0 (85.5)	31.9 (87.9)	36.5 (89.2)
M total input-N	7.1	14.5	25.1	30.4	36.3	40.9
OUTPUT-N ($g.m^{-2}$)						
N Water-N (dissolved + particulate)[b]	6.4 (90.1)	7.8 (53.8)	8.6 (34.3)	8.1 (26.6)	9.5 (26.2)	10.3 (25.2)
O Shrimp-N[b]	0.9 (12.7)	3.0 (20.7)	5.4 (21.5)	7.6 (25.0)	6.3 (17.3)	6.2 (15.2)
P N in excess in sediment[b]	-	2.3 (15.9)	5.0 (20.1)	4.9 (16.1)	11.3 (31.2)	15.7 (38.4)
Q N to atmosphere[b]	-	1.4 (9.7)	6.1 (24.1)	9.9 (32.4)	9.2 (25.3)	8.7 (21.3)

[a] The different compartments of nitrogen were calculated as follow: line C = N concentration in feed x total weight of feed ; line D = N concentration in shrimp x weight of shrimp harvested ; line E = (D/C) x 100 ; line F = C-D ; line G = F/B ; line H = F/A ; line I = N-K ; line J = H-I ; line K = (nitrogen concentration in inflow water x volume of inflow)/A ; line L = C/A ; line M = K+L ; line N = (nitrogen concentration in outflow water x volume of outflow)/A ; line O = D/A ; Line P = see text ; line Q = M-(N+O+P).

[b] Between brackets is expressed the percentage of the compartment versus total input-N (line M).

These values allowed to calculate lines K and N on **table 11**, and, consequently, the budget of waste-N in outflow water (line I, **table 11**). Two more compartments have to be determined. They are, firstly, nitrogen surplus in the sediment and, secondly, nitrogen released to the atmosphere, through diffusion and denitrification. The sum of both these compartments (line J on **table 11**) can be calculated thus: [(surplus in sediment-N + atmosphere-N).m^{-2} = total quantity of waste.m^{-2} generated in ponds - waste.m^{-2} discharged out of the ponds with outflow]. This corresponds to line J = line H - Line I on **table 11**. To determine the amount of nitrogen in excess into the sediment, for the ponds with 4, 7, 15, 22 and 30 shrimp.m^{-2}, respectively, we calculated the excess amount of nitrogen in the sediment having accumulated above the original level of the pond floor (line P, **table 11**). For this purpose, the concentration of total nitrogen measured in the sediment of the pond with 1 shrimp.m^{-2}, i.e. 1.50 ± 0.23 $mg.g^{-1}$ sediment **(table 11)**, was taken as reference. In this pond the nitrogen input from feed pellets was very small, 2.7 $g.m^{-2}$ (line L, **table 11**) during the whole rearing cycle, and the total amount of generated waste-N was 1.8 $g.m^{-2}$ (line H, **table 11**). Furthermore, in this pond, no accumulation of nitrogen appeared to have taken place in the sediment during the rearing cycle (see **table 11** and discussion). The nitrogen surplus in the sediment was calculated as follow: surplus sediment-N ($g.m^{-2}$) = [(concentration of total N in sediment of pond - concentration of total N in sediment of pond 1 shrimp.m^{-2}) x total dry weight.m^{-2} of accumulated sediment]. This last term, shown on **table 11**, was calculated taking into account (1) the volume of accumulated sediment, (2) the mean density of the wet sediment (1.37 g.cm^{-3}) and (3) the mean water content of the sediment (52.8 %).

The nitrogen concentration in feed pellets and in shrimp, determined in 10 samples was 70.1±1.1 and 32.2±4.6 mg.g^{-1} wet weight respectively. In calculating the budget, the water flowing into each pond and pumped in the same channel are considered the same and presenting the same characteristics. The volume of water exchanged (inflow or outflow) during the whole rearing cycle, used in the calculation of the nitrogen budget (**table 11**), was calculated as follow: total V exchanged (l.m^{-2}) = daily exchange (i.e. 130 l.m^{-2} d^{-1})x 183d = 23790 l.m^{-2}. The input due to rainfall was considered as negligible, representing less than 0.4 % of the volume of renewal water. Due to the nature of the soil, no seepage was observed. The ratio of feed pellets-N used to produce shrimp (**table 11**, line E) decreased from 34.6 % to 17.0 % from pond with 1 shrimp.m^{-2} to pond with 30 shrimp.m^{-2}, respectively. The total quantity of waste-N in ponds (line H) increased with stocking density, from 1.8 to 30.3 g.m^{-2}. **Figure 7** shows the relationship between waste-N generated in the pond (line H) on the one hand and, on the other hand, the quantity of waste-N released through renewal water (line I), and with waste-N accumulated in the sediment and/or released to atmosphere(line J).

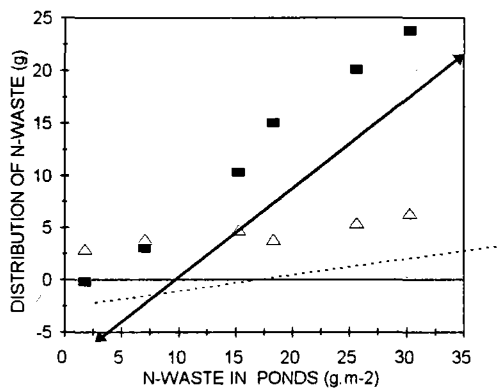


Figure 7. Distribution of waste.N in relation to the total quantity of waste - N generated in the ponds. - ■ - Sediment + atmosphere ; - ∇- Outflow.

There is a linear relationship between waste-N generated in the pond per unit area (x) and the quantity of waste-N discharged during water change (y) which yield an equation ($y = 0.11\ x + 4.10$; $r^2 = 0.8387$). For sediment accumulation and/or atmospheric release the equation $y = 0.892\ x - 3.981$ ($r^2 = 0.9938$) applies. The amount of nitrogen accumulated in the pond sediment + atmosphere (**table 11,** line J) increased with stocking density, ranging from -0.2 to 24.4 g.m^{-2} in the ponds with 1 and 30 shrimp.m^{-2} respectively. In rearing 1 shrimp.m^{-2} the quantity of wastes released with the outflow is higher than the quantity of waste accumulated in the sediment and/or released to the atmosphere. For stocking densities equal to or higher than 4 shrimp.m^{-2}, the proportion of waste released with outflow becomes lower than that accumulated in sediment and/or released to the atmosphere. In the pond with 1 shrimp.m^{-2}, the amount of waste-N released with the outflow (line I) was greater than the total amount of waste produced in the pond (line H). This explains the negative value concerning waste accumulated in the sediment and/or released to the atmosphere for that pond (line J).

Table 11 also shows the compartments into which the origin and the fate of nitrogen were partitioned. The relative proportions of nitrogen entering the ponds with the inflow (line K) and with feed pellets (line L) varied inversely to each other. Calculated excess nitrogen in the sediment compartment (line P) varied from 2.3 to 15.7 g.m^{-2}, respectively, in the ponds with 4 and 30 shrimp.m^{-2} representing 15.9 % to 38.4 % of the nitrogen output. Respective values for nitrogen released to the atmosphere (line Q) ranged from 1.4 to 9.9 g.m^{-2}, which was 9.7 % to 32.4 % of nitrogen total output.

Table 12 shows the fate of feed-N in the different compartments. There is a decrease in Feed-N utilisation by the shrimp with stocking density, from 29.7 % to 17 % for stocking density 4 and 30 shrimp.m^{-2} respectively. In the mean time, the stocking of nitrogen in the sediment increased (from 22.8 to 43 %), and the discharge by outflow decreased (from 33.7 to 16.2 %). Released in atmosphere represents from 13.9 to 38.1 %.

Table 12. Fate of Feed-N in rearing ponds: influence of stocking density in extensive to semi-intensive conditions.

Stocking density ((biomass	Water renewal (%)	% in shrimp	% in outflow	% in sediment	% to atmosp.
4	10	29.7	33.7	22.8	13.9
7	10	26.1	20.3	24.2	29.5
15	10	29.2	14.2	18.8	38.1
22	10	19.7	16	35.4	28.8
30	10	17.0	16.2	43.0	23.8

Figure 8 shows that it exists an inverse relationship between shrimp size at harvest and total wastes generated in the ponds.

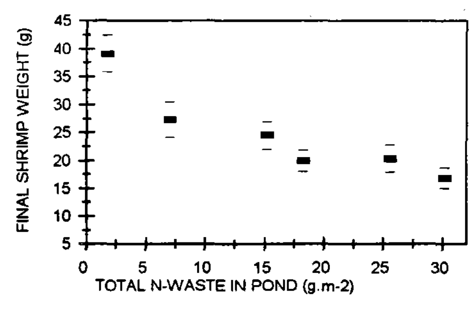


Figure 8. Relationships between the shrimp weight and the total quantity of waste-N in the ponds (Mean ± standard deviation).

The import-export budget (dry weight) in the ponds was determined to elucidate the respective parts derived from seston particles and feed pellets in the raising of the sediment level. The mean water content of the feed pellets, shrimp and sediment were 10.8 %, 73.1 % and 52.3 % respectively. **Table 13** shows that the potential contribution of feed pellets and that of seston in the raising of the sediment level cannot exceed from 94.6 to 381.7 g.m^{-2}, depending on the pond. This equates to 1.3 % to 2.9 % of the total mass of the raising. A similar analysis for input of mineral material was performed. The content of mineral components in shrimp and feed pellets, determined after incineration at 450° C, was 17.2 % and 10.6 % respectively.

Table 13 shows that from 0.2 % to 2.4 % of the mineral material in the deposited sediment can potentially be originated from feed pellets and seston particles.

Table 13. Dry material budget in ponds.

Stocking density	1	4	7	15	22	30
weight of dry sediment ($g.m^{-2}$)[a]	3233	6466	12932	16166	22632	29098
INPUT						
inflow ($g.m^{-2}$)	858.8	858.8	858.8	858.8	858.8	858.8
feed pellets ($g.m^{-2}$)	33.4	122.0	244.7	318.0	390.5	443.4
OUTPUT						
outflow ($g.m^{-2}$)	789.8	825.5	868.3	813.6	851.7	863.6
harvest output ($g.m^{-2}$)	7.8	28.1	48.2	68.2	56	56.9
budget (input-output) ($g.m^{-2}$)	94.6	127.2	187.0	295.0	341.7	381.7
% budget/sediment (dry material)[b]	2.9	2.0	1.4	1.8	1.5	1.3
% budget/sediment (mineral)[b]	2.4	0.9	0.3	0.5	0.3	0.2

[a] This is the weight of sediment corresponding to the raising of the sediment level during the rearing cycle.

[b] This corresponds to the ratio of the potential part of the input (seston + feed pellets) in the raising of the sediment level.

1.2.3.1.1.3. Discussion

Increasing shrimp stocking density resulted in an increasing input of organic matter into the pond, through feed pellets, and a decrease in the feed efficiency (increase in FCR). As a result, more wastes were produced. When organic wastes accumulated in the sediment (unconsummated feed pellets, feces...) are degraded, ammonia, nitrite and nitrate are formed (Blackburn *et al.*, 1988 ; Garnier and Barillier, 1991). Furthermore, ammonia is released in the water through the excretion of the shrimp (Wajsbrot *et al.*, 1989). These nutrients support primary production and phytoplankton growth. Although the average total suspended matter content in the outflow does not increase with stocking density, there is an increase in the ratio of organic components, such as nitrogen and chlorophyll-a, in suspended solids. Furthermore during the rearing cycle, an increase in the concentrations of chlorophyll-a and particulate nitrogen in the water occurred, from its beginning to its end. This give evidence for the development of a phytoplanktonic bloom, specially in ponds with the highest stocking densities. Concerning the dissolved elements, the effluents showed a decrease in inorganic-N nutrients, especially $(NO_2^- + NO_3^-)$-N. This is a classical pathway to remove the mineral nutrients from water, and take advantage of in-pond digestion processes to reduce soluble pollutants in the discharge, through primary production (Hopkins *et al.*, 1993 ; 1995).

Unconsummated feed pellets and feces can increase the concentration of particulate and dissolved organic matter in the sediment. Furthermore, the residues of mineralisation of this organic matter, especially $(NH_4^+ + NH_3)$-N can accumulate. This accumulation grows in importance as the stocking density rises. Rinj (1996) noted that the most common problem in ponds with feed input is the accumulation of organic matter and of inorganic nitrogen, particularly ammonia, in the sediment. Few studies have been done on the impact of the stocking density of shrimp on sediment and pore water parameters. Furthermore, authors do not use the same units to express the concentrations of elements and compounds. Some express their results either in terms of pore water, or of total wet sediment, or even in terms of total dry sediment. There is also a great variability in the method of sampling, for example, thickness of the sampled layer, which can lead to very different results (Blackburn *et al.*, 1988). Chien (1989) showed that in shrimp ponds in Taiwan, ammonium (NH_3-N) levels in sediment range from 12.8 to 14.3 mg.kg^{-1} wet weight. Morales *et al.* (1991) found ammonia concentrations ($NH4^+$+NH_3) ranging from 23.4 to 236 mg.kg^{-1} wet sediment, from shrimp ponds in Spain. For (NO_2^-+NO_3^-)-N, concentrations can range from 6.4 to 16.2 mg.kg^{-1} wet weight (Morales *et al.*, 1991) These values (ammonia and nitrates) are far higher than those observed in the present study.

The fate of nitrogen entering the ponds in the inflow and feed pellets shows that increasing the input increases also the rate of N accumulation in the sediment, which can account for up to 38.4 % of the total input. The calculated proportion of nitrogen released to the atmosphere, through diffusion of NH_3 and denitrification, ranged from 9.7 % to 32.9 %., although it should be remembered that these values are based on the strong likelihood that the pond stocked at 1 shrimp.m^{-2} did not accumulate nitrogen during the rearing cycle (see further discussion below). Our results concur with the work of Briggs and Funge-Smith (1994) and Funge-Smith and Briggs (1996), who reported that in shrimp ponds the percentage of nitrogen released to the atmosphere range from 13 to 30 % of the total nitrogen output. In absolute terms, nitrogen released to the atmosphere amounted to between 1.4 and 9.9 g.m^{-2}, which represents from 7.7 to 54.1 mg.m^{-2}.d^{-1}, similar to values reported by Gouleau *et al.* (1996) who showed denitrification rates ranging from 2.79 to 9.61 mg.m^{-2}.d^{-1} in ponds with oyster biodeposits. Much smaller denitrification rates have been found by some other authors. For example, Nishio *et al.* (1983) showed denitrification rates of 13.3 to 61 µg.m^{-2}.d^{-1} in coastal sediments. Kaplan *et al.* (1979) showed denitrification activity in salt marshes to range from 0 to 120 µg. m^{-2}.d^{-1}. These variations in the fluxes of denitrified and/or diffused nitrogen may owe their origin to differences in parameters such as temperature, aeration, or dissolved oxygen levels (Briggs and Funge-Smith, 1994 ; Payne, 1973).

For the pond with 1 shrimp.m^{-2}, the nitrogen output (water + shrimp) was higher than the nitrogen input (water + feed pellets). This means that in this pond the sediment was most probably a potential source of nitrogen rather than an accumulator. Reymond and Lagardère (1990) showed that meiofauna may constitute an important part of the feeding ration of shrimp in ponds where the stocking density is low. In that case, the natural food web, from nutrients to shrimp, would constitute a way of removing accumulated wastes from sediments, through primary production and meiofauna. For higher stocking densities, waste accumulation is greater than the « decontamination » through the natural food web. Reymond and Lagardere (1990) showed that at high stocking density, meiofauna may constitute a substantial source of nutrition only at the beginning of rearing. Furthermore, Allan and Maguire (1992) noted, that the decline in growth of *Penaeus monodon* when stocking densities are increased, could be due to decreased grazing by shrimp on natural prey in ponds. Allan *et al.* (1995) noted that prawns grow faster in prepared ponds where meiofauna is abundant.

The relationship between stocking density and final weight and/or survival rate of shrimp is inverse. Increasing initial stocking density has for consequences an increase of organic matter input in the pond, through the increasing input of feed pellets. The quantity of wastes, expressed as N-g.kg^{-1} reared shrimp is not identical from one pond to the other. It increased with stocking density. It appears that this quantity of waste may be related not only to initial stocking density, but, also, to the fact that shrimps dying during the rearing cycle may account as wastes, as well as the overfeeding which may result of the mortality and of the difficulties occuring in assessing the survival rate of shrimps, and as a consequence, in assessing the reared biomass during the rearing cycle. It then appears that the relationship between the quantity of wastes may be magnified through the differences in mortalities of shrimps, observed in relation with stocking densities. Increasing the rearing density, and, then the production of wastes has for consequences an increase in the capacity of the production of nutrients which could be toxical for the shrimps. In this study, there is no evidence that concentration of nutrients in the water could have been solely responsible for the low growth rate and survival (Allan *et al.*, 1990 ; Chen *et al.*, 1990b ; Chen and Lei, 1990). Concerning oxygen, a decrease in concentration occurs during the night, although the oxygen concentration found harmful to shrimp (Allan and Maguire, 1991) were lower than those occurring at dawn in the present study, even at the end of the rearing period. It has been noted that the pond floor level can be raised by 0.5 to 4.5 cm during the rearing cycle. The input of feed pellets and particles in the inflow, alone cannot account for this accumulation. Indeed, for the pond stocked at 30 shrimp.m^{-2}, in which the floor level rose the most markedly, the inputs due to seston and feed pellets combined, represent at most only 1.3 % and 0.2 %, respectively of total dry solid and mineral material. Since the hydraulic regime was similar for all ponds, only the swimming activity of shrimp can lead to erosion of the bottom and may explain such the rise in sediment level, and such a difference between the ponds. This means that shrimp lives in close contact with the sediment were an increase of (NH_3+NH_4^+)-N concentrations occurred during the rearing cycle, more specifically for the highest stocking density. Allan *et al.* (1990) noted that reduced concentrations of dissolved oxygen significantly increase acute toxicity of ammonia to *Penaeus monodon*. It is therefore possible that the concentrations of nutrients in the sediment, or at the sediment-water boundary, and the oxygen concentration at that level, may account for a large part in the toxicity of the environment for shrimp. As a consequence, sediment characteristics, and more specifically the pore water, rather than the concentration of nutrients in the water, should be taken into account to explain death rates decreasing growth performances, either or not they act in synergy with oxygen concentrations.

1.2.3.1.2. For intensive rearing

1.2.3.1.2.1. Specific characteristics of this experiment

Four rearing were conducted in 13 m^2 rectangular outdoors ponds with central water drainage. Water depth was 1 m. Sea water was obtained from the lagoon. Each pond had a flow regulation valve. Three to 5 grams average body weight shrimp were stocked in order to place the experiment period when shrimp growth is better and almost linear. Initial shrimp loads tested were 197, 295, 394 and 492 g.m^{-2}, corresponding to an initial stocking density ranging from 50, 75, 100, and 125 shrimp m^{-2} respectively. Shrimp were fed a local commercial pellet (FUC containing 90 % dry matter and 45 % proteins in average). All ponds were equipped with electrical automatic feeders to ensure eight meals per day. Cultures lasted 29 days. Water exchange rate, similar in each pond, was 20 % per day. Aeration was provided through 2 air lifts per pond resulting in the injection of 3.5 to 4 Nm^3(air).m^{-3}(water).hour^{-1}, and was stopped daily during 2 hours (from 8 am to 10 am).

In order to determine the concentrations of nutriments-N, and of parameters dealing with suspended solids, water sampling in inflow and in outflow were carried out once a week, at 0800 h in the morning, just before aeration was stopped. Water quality measurements (oxygen, pH, T°) were performed twice a day, at 8 a.m. and 4 p.m..

Sludge settled on the bottom of the pond were collected at harvest, dried, weighed and analysed.

Survival rate was obtained from total shrimp counts done at stocking and at harvest. Shrimp mean growth was calculated from weights sampled at stocking; mean culture and at harvest. Given feed amounts were closely checked, weighed, and total amount calculated. and feed conversion ratio was calculated.

1.2.3.1.2.2. Results

Zootechnical results are presented in **table 14**. Shrimp survival ranges from 78 to 83 % and growth rate from 0.186 to 0.225 $g.day^{-1}$. Both decrease when initial shrimp load increases. Food conversion ratio (FCR) varies from 1.7 to 2.1, increasing with the shrimp load. These zootechnical performances are well representative of good intensive cultures.

Table 14. Effect of culture intensification. Stocking and harvest data.

Initial shrimp load ($g. m^{-2}$) stocking density ($shrimp.m^{-2}$)	197 50	295 75	394 100	492 125
Surface of pond (m^2)	13	13	13	13
Stocking density ($shrimp. m^{-2}$)	50	76	101	126
Initial mean weight[a] (g)	3.9	3.9	3.9	3.9
Initial biomass (kg)	2.56	3.84	5.12	6.40
Duration of rearing (day)	28	29	29	28
Survival rate (%)	83	82	78	78
Growth rate ($g.day^{-1}$)	0.225	0.214	0.207	0.186
F.C.R[b].	1.7	1.7	1.9	2.1
Final density ($shrimp. m^{-2}$)	42,0	62,0	79,0	99,0
Final biomass (kg)	5.60	8.12	10.14	11.66
Final weight[a] (g)	10.2	10.1	9.9	9.1
Total feed in pond (kg)	5.01	7.39	9.54	11.01
Production ($g. m^{-2}.j^{-1}$)	8.27	11.36	13.32	14.46

[a] Mean of 30 shrimp ± standard deviation.
[b] FCR = Food Conversion Ratio.

A relationship exists between initial stocking density and several zootechnicals parametres. So, growth rate yields an equation: Y (growth rate as $mg.d^{-1}$) = 0.00013 loading + 0.2514 ($r = 0.974$ $p<0.01$), while the formation of waste yieds an equation: Y (waste $g.kg^{-1}$ shrimp) = 0.108 loading + 68.884 ($r = 0.976$ $p<0.01$).

Hydrobiological data are shown in **table 15**. Regarding dissolved oxygen average morning and evening concentrations range respectively from 7.2±0.4 to 7.3±0.4 $mg.l^{-1}$ and from 7.3±0.6 to 7.5±0.6 $mg.l^{-1}$. No significant difference can be observed between morning and evening concentrations. It is to be noticed that air diffusers worked in the ponds for 22 hours per day.

Table 15. Effect of culture intensification. Variations of hydrobiological parameters in the ponds. Results are expressed as means ± standard deviations. Ranges are shown between brackets.

Initial shrimp load (g. m^{-2}) stocking density (shrimp.m^{-2})	197 50	295 75	394 100	492 125
Oxygen morning (mg.l^{-1})	7.3 ± 0.4	7.3 ± 0.4	7.3 ± 0.4	7.2 ± 0.4
	(5.6-8.4)	(5.7-8.0)	(5.6-8.3)	(5.5-8.2)
Oxygen evening (mg.l^{-1})	7.4 ± 0.6	7.4 ± 0.5	7.5 ± 0.6	7.3 ± 0.6
	(6.1-8.4)	(6.1-8.3)	(6.0-8.4)	(5.9-8.2)
pH morning	8.2 ± 0.1	8.0 ± 0.1	8.1 ± 0.2	7.9 ± 0.1
	(7.8-9.0)	(7.8-9.1)	(7.6-9.0)	(7.6-9.1)
pH evening	8.6 ± 0.3	8.6 ± 0.4	8.6 ± 0.3	8.5 ± 0.4
	(7.9-8.3)	(7.8-8.3)	(7.8-8.2)	(7.7-8.2)
Temperature morning (°C)	28.4 ± 0.6	28.1 ± 0.6	28.2 ± 0.6	28.2 ± 0.6
	(27.0-29.5)	(26.6-29.2)	(27.0-29.3)	(26.8-29.4)
Temperature evening (°C)	30.7 ± 1.0	30.3 ± 0.9	30.5 ± 0.9	30.6 ± 0.9
	(28.9-32.3)	(28.6-32.0)	(28.9-32.1)	28.7-32.1)
Salinity (ppt)	35.5 ± 0.2	35.7 ± 0.2	35.4 ± 0.3	35.6 ± 0.3

Respective average pH values of 8.2±0.1, 8.0±0.1, 8.1±0.2 and 7.9±0.1 in the morning increase to 8.6±0.3, 8.6±0.4, 8.6±0.3 and 8.5±0.4 respectively in the afternoon. Temperature is comprised for all cultures between 28.2±0.6 and 28.4±0.6° C in the morning and between 30.3±0.9 and 30.7±1.0° C in the evening.

Salinity stands between 35.4±0.3 and 35.7±0.2 ‰ in all ponds.

Compounds average concentrations in inflows and outflows are given in **Table 16**. Concentrations of all parameters related to particulate suspended matter, increase between inflow and outflow for all shrimp loads. Concentration of total suspended matter is 15.6±10.0 mg.l^{-1} in inflow and stands above 53.4±27.4 mg.l^{-1} in outflow. Enrichment of particulate material is mainly organic, with percentage of organic matter increasing from 34±6 % to a minimum of 67±14 % between inflow and outflow. Particulate nitrogen concentrations are 0.3±0.1 mg.l^{-1} in inflow and above 2.0±1.4 mg.l^{-1} in outflow.

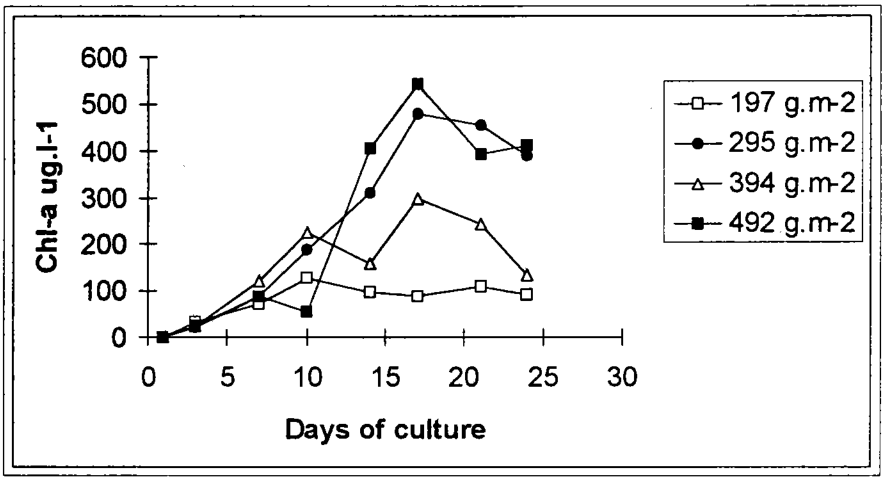
Table 16. Effect of culture intensification. Concentrations of main water quality parameters in inflowing and outflowing water. Results are expressed as mean ± SD. Range are shown between brackets.

	Inflow	Outflow			
Initial shrimp load ($g.m^{-2}$)		197	295	394	492
stocking density ($shrimp.m^{-2}$)		50	75	100	125
Particulate					
Total Susp. matter ($mg.l^{-1}$)	15.6 ± 10,0	53.4 ± 27.4	74.1 ± 41.9	75.4 ± 36.2	92.5 ± 55.5
	(5.2-25.2)	(5.5-81.0)	(4.3-137.7)	(5.5-104.7)	(6.7-171.2)
Organic matter ($mg.l^{-1}$)	4.9 ± 2,6	36.5 ± 19.3	52.6 ± 29.2	55.3 ± 28.7	69.7 ± 42.6
	(2.1-7.1)	(2.4-64.7)	(2.1-85.9)	(2.7-89.4)	(2.4-118.1)
Organic matter (% TSM)	34 ± 6	67 ± 14	70 ± 13	71 ± 12	70 ± 15
	(28-40)	(43-90)	(48-88)	(49-85)	(36-86)
Chl-a ($\mu g.l^{-1}$)	n.a. [a]	77 ± 42	241 ± 193	151 ± 104	240 ± 218
		(0.2-128)	(0.2-477)	(0.2-299)	(0.2-542)
Pheop. ($\mu g.l^{-1}$)	n.a. [a]	15 ± 18	26 ± 24	29 ± 29	52 ± 61
		(0.4-49)	(0.3-70)	(0.4-87)	(0.4-184)
Chl.a / Org.matter ($\mu g.mg^{-1}$)	n.a. [a]	2.1 ± 1.0	3.5 ± 2.2	2.3 ± 1.2	2.3 ± 2.1
		(0.1-3.3)	(0.1-6.3)	(0.1-4.1)	(0.1-5.9)
Particulate-N ($mg.l^{-1}$)	0.3 ± 0.1	2.0 ± 1.4	3.7 ± 2.8	3.0 ± 2.1	4.3 ± 3.7
	(0.14-0.39)	(0.1-3.5)	(0.1-6.7)	(0.1-4.8)	(0.1-8.8)
Dissolved					
(NH4+-NH3)-N ($\mu g.l^{-1}$)	186 ± 128	168 ± 181	554 ± 663	328 ± 333	617 ± 675
	(41-281)	(6.9-454)	(32-1529)	(77-850)	(52-1396)
(NO2-NO3)-N ($\mu g.l^{-1}$)	34.8 ± 11.2	16.3 ± 5.2	25.6 ± 10.3	20.8 ± 8.8	34.1 ± 16.5
	(25.2-47.1)	(12.4-25.0)	(14.0-41.0)	(12.4-35.3)	(12.4-56.0)
Organic-N ($\mu g.l^{-1}$)	1264 ± 552	2463 ± 3347	2450 ± 3185	2671 ± 3005	3588 ± 4678
	(856-1892)	(534-8326)	(358-7897)	(240-6013)	(142-8871)
Total dissolved-N ($\mu g.l^{-1}$)	1485 ± 666	2648 ± 3497	3030 ± 3607	3020 ± 3305	4116 ± 5297
	(922-2221)	(585-8792)	(598-8863)	(338-6750)	(229-10280)

[a] not analysed

Particulate nitrogen ranges from 2.0±1.4 to 4.3±3.7 $mg.l^{-1}$ in outflow when shrimp load increases. Phytoplancton growth is enhanced by shrimp load, concentration of chlorophyll-a in outflow increasing from 77±42 to 240±218 $\mu g.l^{-1}$. It is to be noticed that elements and compounds dealing with suspended solids increase in the outflow with increasing stocking density.

Regarding the dissolved material, the same observations can be done: concentrations increase between inflow and outflow and in outflow with increasing shrimp loads. This inflow to outflow increase is evident for organic nitrogen (1264±552 $\mu g.l^{-1}$ in inflow and 2463±3347, to 3588±4678 $\mu g.l^{-1}$ in outflow). For ammonia nitrogen, there is no increase in the concentration between inflow and outflow of the pond with the lowest loading (186±128 $\mu g.l^{-1}$ in inflow and 168±181 in outflow). For highest loading the increase of ammonia nitrogen concentration may be seen, up to 617±675 $\mu g.l^{-1}$ in outflow, compared to inflow. No increase in the concentrations of $(NO_2^-+NO_3^-)$-N between inflow and outflow can be observed. High standard deviations for all parameters are observed, meaning the strong variability of each of them during the rearing period. This strong variability is due to the development of phytoplanktonic bloom in the ponds, with, as consequences, an increase in the concentrations of parameters dealing with suspended solids, and with nutrients. As an example, **figure 9** shows the variations of Chl-a and particulate nitrogen with shrimp load during the rearing. It can be observed an increase in the concentrations. The highest concentrations are observed after 15 days rearing duration. The lowest concentrations of chl-a and of particulate nitrogen are observed in the pond with the lowest stocking density. Inversely, the highest concentrations are shown in the pond with the highest stocking density. In that pond, chl-a concentrations reach up to 500 µg.l^{-1}. Particulate nitrogen reach up to 9 mg.l^{-1}.



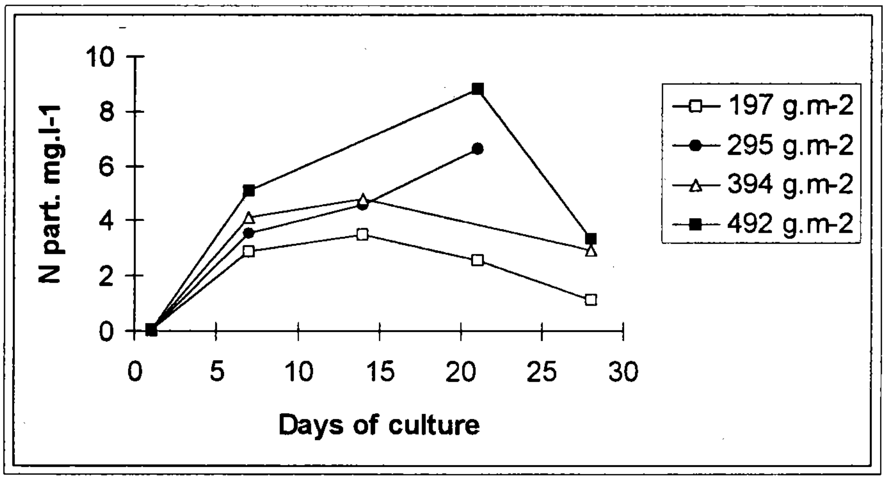


Figure 9. Variations of Chl-*a* and particulate N concentrations in relation to stocking biomass.

Characteristics of collected sludge are shown in **table 17**. Collected amount of sludge increases with shrimp load from 870 to 1156 g dry weight. Percentage of organic matter in those collected sludge ranges from 25 to 28 %. Total nitrogen concentrations ranges from 13.0 to 14.1 mg.g^{-1} dry weight.

Table 17. Effect of culture intensification. Sludge characteristics at the end of culture.

Initial shrimp load (g.m^{-2})	197	295	394	492
stocking density (shrimp.m^{-2})	50	75	100	125
collected dry weight (g)	870	944	1024	1156
organic matter (% d.w.)	27	28	27	25
total N (mg.g^{-1} d.w.)	13,0	13,9	14,1	13,9

Nitrogen budget is shown on **table 18**. Line G shows that there is an increase in waste production, expressed as quantity of waste-N produced per Kg of shrimp produced, with the stocking biomass (i.e. stocking density). The quantity of wastes ranges from 93 to 124 $g.kg^{-1}$ shrimp produced, for ponds loaded with 197 and 492 g $shrimp.m^{-2}$ respectively (**figure 10**). Nitrogen input by inflowing water (line L) ranges from 10.8 to 13.7 $g.m^{-2}$. When shrimp load increases, input by feed increases from 27.8 to 61.1 $g.m^{-2}$. Feed share of total inputs (line M) increases with the load from 72.0 to 82.8 % while the water share (line L) decreases from 28.0 to 17.2 %. Nitrogen output by outflowing water (line O) (27.4 to 60.6 $g.m^{-2}$) by sludge (line P) (0.9 to 1.2 $g.m^{-2}$) and by shrimp production (line Q) (6.3 to 11.0 $g.m^{-2}$) increases with shrimp load. Nitrogen export to the atmosphere (line R) (ammonia diffusion and denitrification) varies from 4.0 to 0.9 $g.m^{-2}$.

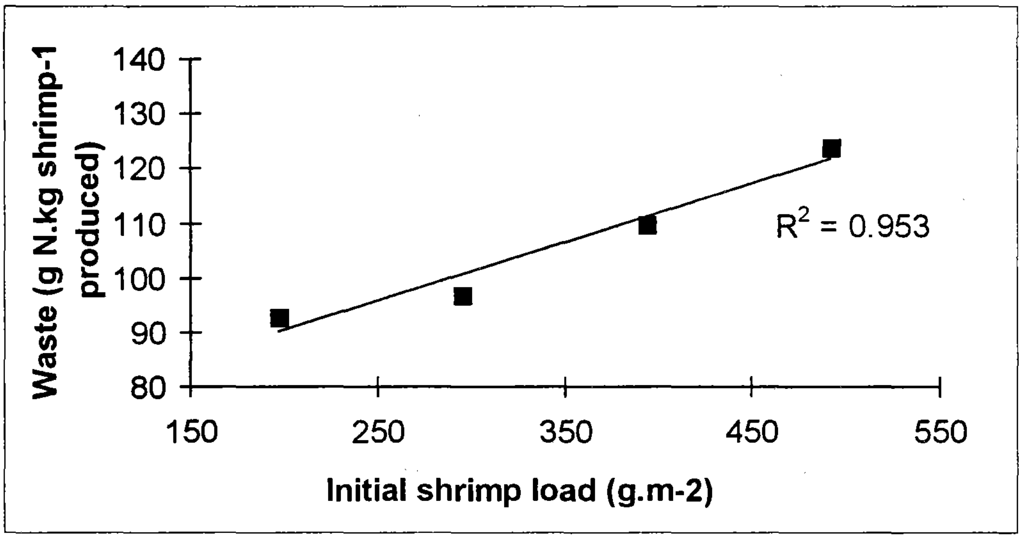


Figure 10. Production of waste-N in relation with shrimp biomass loading.

Table 18. Effects of culture intensification on the nitrogen budgets in ponds[a].

Initial shrimp load ($g.m^{-2}$)		197	295	394	492
stocking density ($shrimp.m^{-2}$)		50	75	100	125
A	surface of pond (m^2)	13	13	13	13
B	shrimp production (g wet weight)	3011	4283	5021	5261
C	total feed-N ($g.pond^{-1}$)	361,4	533,0	687,7	794,3
D	shrimp produced-N ($g.pond^{-1}$)	81,9	115,7	136,5	143,0
E	feed efficiency-N (%)	22.7	21.7	19.8	18.0
F	total waste-N ($g.pond^{-1}$)	279.5	417.3	551.2	651.3
G	waste-N ($g.kg^{-1}$ shrimp produced)	93	97	110	124
H	total waste-N ($g.m^{-2}$)	21.5	32.1	42.4	50,0
I	outflow water waste-N ($g.m^{-2}$)	16.6	27.1	34.1	47.9
J	sludge waste-N ($g.m^{-2}$)	0.9	1.0	1.1	1.2
K	atmosphere waste- N ($g.m^{-2}$)	4.0	3.9	7.1	0.9
	Input-N ($g.m^{-2}$)				
L	water-N (dissolved + particulate)[b]	10.8 (28.0)	11.0 (21.2)	13.7 (20.5)	12.6 (17.2)
M	feed pellets-N[b]	27.8 (72.0)	41.0 (78.8)	52.9 (79.5)	61.1 (82.8)
N	total input-N	38.6	52,0	66.5	73.7
	Output-N ($g.m^{-2}$)				
O	water-N (dissolved + particulate)[b]	27.4 (71.1)	38.2 (73.4)	47.8 (71.8)	60.6 (82.2)
P	sludge-N[b]	0.9 (2.2)	1.0 (1.9)	1.1 (1.7)	1.2 (1.7)
Q	shrimp-N[b]	6.3 (16.3)	8.9 (17.2)	10.5 (15.8)	11.0 (14.9)
R	atmosphere-N[b]	4.0 (10.0)	3.9 (7.5)	7.1 (10.7)	0.9 (1.2)

[a] The different compartments of nitrogen were calculated as follows: line B = harvested shrimp weight less stocked shrimp weight ; line C = nitrogen concentration in feed x feed dry weight ; line D = nitrogen concentration in shrimp x B ; line E = (D/C) x 100 ; line F = C - D ; line G = F/B ; line H = F/A ; line I = O - L ; line J = nitrogen concentration in sludge x sludge volume ; line K = H - (I+J) ; line L = (nitrogen concentration (dissolved + particulate) in input water x input water volume)/A ; line M = C/A ; line N = L + M ; line O = (nitrogen concentration (dissolved + particulate) in output water x output water volume)/A ; line P = J ; line Q = D/A ; line R = K.

[b] Numbers between brackets are percents of total input-N.

When considered as the percentage of total input (line N), shrimp share (line Q) ranges from 14.9 to 17.2 %, and N-sludge (line P) from 1.7 to 2.2 %. Nitrogen output with outflow (line O) increases from 71.1 % to 82.2 %, with increasing loading. Release to atmosphere decreases from 10.0 to 1.2 %. **Figure 11** shows the sharing of wastes, in relation to the total quantity of wastes produced. It appears that an increase in the total quantity of wastes leads mainly to an increase of wastes in outflowing water.

Table 19 shows the fate of feed-N in the different compartments. There is a decrease in Feed-N utilisation by the shrimp with stocking density, from 22.7 % to 18 % for stocking density 50 and 125 $shrimp.m^{-2}$ respectively. In the mean time, the share of feed-N accumulated with sludge decreased (from 3.2 to 2.0 %), and the discharge with outflow increased (from 59.7 to 78.6 %). Released in atmosphere decreased from 14.4 to 1.5 %.

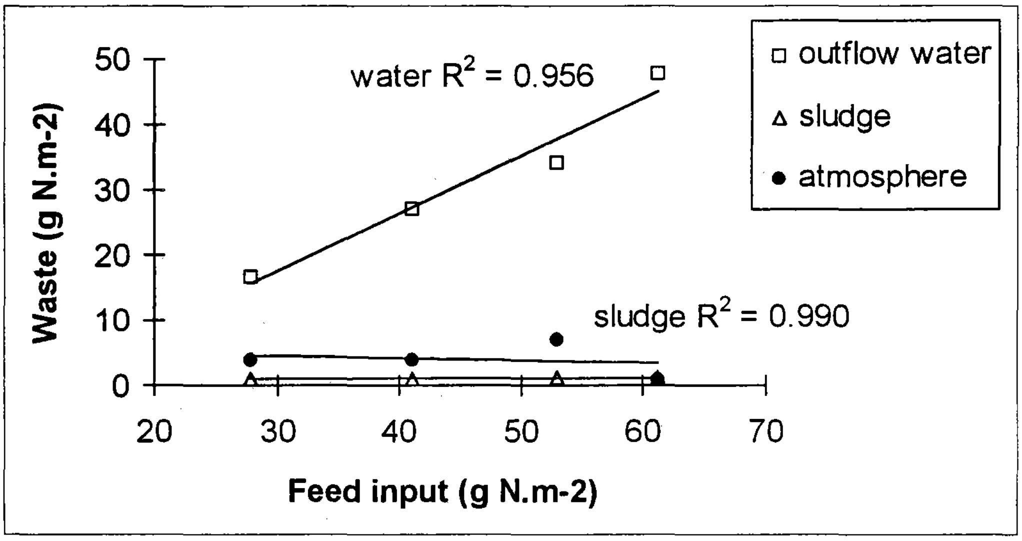


Figure 11. Fate of waste-N in ponds, in relation to intensification, expressed as feed-N input.

Table 19. Fate of Feed-N in rearing ponds: influence of stocking density in intensive conditions.

Stocking density (biomass)	Water renewal (%)	% in shrimp	% in outflow	% in sediment	% to atmosp.
50 (197)*	20	22.7	59.7	3.2	14.4
75 (295)*	20	21.7	66.3	2.4	9.5
100 (394)*	20	19.8	64.5	2.1	13.4
125 (492)*	20	18.0	78.6	2.0	1.5

* between bracket is shown the initial biomass in the pond, expressed as $g.m^{-2}$ pond.

1.2.3.1.2.3. Discussion

In the case of this study the increase of rearing density does not induce a significant increase of mortality, which stands between 78 and 83 % depending on the pond. However the zootechnical results show an influence of density on growth performance, with growth rate decreasing from 0.225 $g.d^{-1}$ to 0.186 $g.d^{-1}$ when rearing density increases. This also means increasing FCR (from 1.7 to 2.1) and then a relative enlargement of waste produced, from 93 to 124 $g.m^{-2}$ waste-N. These observations are similar to those concerning the earthen ponds for semi-intensive rearing. Nevertheless, it is to be noticed that, in intensive rearing in concrete ponds, mechanical aeration was operating 22 hours per day, while in earthen ponds no aeration was performed. In the case of intensive rearing in concrete ponds, mortalities cannot explain the amplification of waste production, expressed as waste-N.kg shrimp $reared^{-1}$ As a matter of fact, the difference between the mortalities observed between ponds (from 83 to 78 %) is 6 %, the excess of wastes is 33 % (from 93 to 124 N-$g.kg^{-1}$ shrimp reared) from the less to the most intensive pond. Reasons for the decrease in growth performance are likely to be investigated elsewhere than in oxygen concentrations during the culture period. As a matter of fact these experiments have been conducted with a daily aeration period of 22 hours using air lifts. Oxygen concentrations measured in the morning have never been lower than 5.6 $mg.l^{-1}$. These values are clearly higher than those said to be toxic for Penaeid shrimp. Critical DO levels for normal growth are reported to be between 1.2 and 1.9 $mg.l^{-1}$ for *Penaeus vannamei* (Seidman *et al.*, 1985) and 1.2 and 2.2 $mg.l^{-1}$ for *Penaeus monodon* (Allen *et al.*, 1991). According to

Fast *et al.* (1992), DO concentrations for «normal» growth are probably 3.7 $mg.l^{-1}$ or higher which is confirmed by Lawrence (1995) who recommended 3.5 to 4 $mg.l^{-1}$ or more for *Penaeus stylirostris.* Concerning pH, all ponds included, the lowest and highest values observed were 7.6 and 9.1 respectively. According to Tsai (1990) lethal level threshold for Penaeidea are respectively 4.8 and 10.6 with optimum growth between 6.6 and 8.5. However organic nitrogen compounds in water display high concentrations. For instance organic-N concentration, which increases with rearing density, can reach mean values beyond 3500 $\mu g.l^{-1}$ in the ponds. Same thing occurs for $(NH_4^+ + NH_3)$-N concentrations which increase with rearing density. Those concentrations are clearly on top of those observed in earthen ponds (see chapter **1-2-3-1-1-2**). It is therefore possible that an increase of $(NH_4^+ + NH_3)$-N concentrations with stocking density, in addition to high pH and temperatures, induces an increase of NH_3 concentration in water, by shifting NH_4^+-NH_3 ion balance towards NH_3, potentially more toxic to the organisms than NH_4^+ (Colt and Armstrong, 1981).

Nitrogen budgets show an expansion of waste produced when rearing density increases. The main part of waste is found in water. Between 59.7 and 78.6 % of feed-N not taken up by shrimp is actually removed of the ponds with water outflow. It is shown by very high concentrations in outflow of dissolved nitrogen compounds (ammonia and ammonium, nitrates and nitrites, organic-N). Total amount of dissolved nitrogen in outflow can reach 10280 $\mu g.l^{-1}$. It appears that water turn over in ponds brings about an incomplete mineralisation of organic matter, giving high concentrations in outflow of organic-N and of $(NH_4^+ + NH_3)$-N. Meanwhile the primary production does not allow to use up nitrates nor nitrites of pond water.

The deposition of sludge on the pond bottom comprised between 2.0 and 3.2 % of feed-N is limited. Concentrations of organic matter and of nitrogen in these sludge are more or less equivalent whatever the pond. It does not appear therefore a faster mineralisation of sludge in a pond or another. Difference in feed-N deposition share (3.2 % in the 50 shrimp per m^2 pond and 2.0 % in the 125 shrimp per m^2 pond) seems to be more related to the activity of shrimp moving up sludge again to suspension and then to drainage, than to the bacterial activity of mineralisation.

1.2.3.2. <u>Effects of water renewal rate on wastes discharge</u>

1.2.3.2.1. For extensive to semi intensive rearing

1.2.3.2.1.1. Specific characteristics of this experiment

This experiment was carried out in the six earthen ponds, at the Aquaculture Experimental Station of Saint-Vincent, New Caledonia. The mean depth of the water was 1 m. Before the beginning of the experiments, the ponds were emptied and left exposed to the air for 39 days. Then, they were filled with seawater and stocked with *Penaeus stylirostris* P15 post-larvae at 20 $individuals.m^{-2}$. Every week, a sample of shrimp was taken from each pond to determine the mean individual weight. Shrimp were fed 4 times a day with a commercial pelleted feed commonly used in New-Caledonia. Feeding rate was adjusted in relation to both food consumption, monitored using one feeding tray per pond and biomass estimates based on weekly shrimp size sampling. No fertilisers was added to the pond before and during the experiment. No aeration was used. The rearing period ran for exactly 209 days from mars 1996 to October 1996. At the end of the experiment, ponds were drained and shrimp harvested in a net bag over the outlet pipe. The whole crop of each pond was weighted *en masse*. Survival, mean individual weight , total biomass gain were calculated for each pond. The total quantity of food added to each pond was used as an estimate of food consumption. Food conversion ratio (FCR) for each crop was estimated.

All along the experiment, a sequential water exchange was performed every day. During the rearing period, the mean water inflow rates were 10 %, 11 %, 16.9 %, 17.4 %, 21 % and 22.7 % per day for ponds 2, 3, 4, 5, 6 and 7 respectively.

Dissolved Oxygen (DO) and water temperature were recorded in all ponds at half-depth twice daily (6:00 am and 4:00 pm). Salinity and pH were measured twice a week (Monday and Thursday) in the evening (4:00 pm).

Pond water samples (1 litre) were taken twice a week (Monday and Thursday), before water exchange, at half-depth near the outlet pipe.

Sediment samples were taken from each pond at specific stations marked with iron posts at the beginning (day 1) and at the end (day 208) of the rearing period (see chapter **1-2-2-3-1-1-1**). At the end of the experiment, the sediment accumulated on top of the original level was measured for each station. The redox potential was assessed *in situ* using a specific electrode (pH-meter Knick 651 + electrode Cofralab PT5700A) according to the method described by Hussenot *et al.* (1995).

1.2.3.2.1.2. Results

Final and mean results (see **table 20**) show that the ponds with the highest water exchange rate (pond 5 and 6) have the highest survival rates. Survival rates ranged from 23.8 % to 41.8 % and increased significantly ($p<0.05$; $r=0.83$) with higher water exchange rate. Shrimp mean weight at harvest ranged from 23.5g to 27.8g showing a correlation with water renewal rate ($p<0.05$, $r=0.822$). There was a significant ($F=56.7$; $p<0.05$) difference in final mean weights between ponds. It is to be noticed that the lowest food conversion ratio are observed for ponds with the highest water renewal rate.

Table 20. Stocking and harvest data for the six ponds studied and stocked with *Penaeus stylirostris.*

Daily renewal rate (%.day^{-1})	10±0.7 pond 1	11±0.8 pond 2	17±1.2 pond 3	17±1.2 pond 4	21±1.5 pond 5	23±1.6 pond 6
Surface of pond (m²)	1370	1520	1450	1450	1460	1520
Stock. density (shrimp.m^{-2})	20.1	20.3	19.3	20.4	19.5	19.7
Final density (shrimp.m^{-2})	4.79	5.95	5.10	7.10	7.04	8.25
Final Biomass (kg)	182.8	238.6	198.7	263.1	266.6	294.0
Final weight g ± S.D.	27.8±3.3	26.4±3.1	26.9± 3.4	25.9±3.2	25.6±2.7	23.5±2.8
Survival rate (%)	23.8	29.3	26.5	36.2	34.8	41.8
Total feed in pond (kg)	544	634	599	651	684	733
F.C.R.	2.98	2.66	3.01	2.44	2.60	2.49
Production (kg.ha^{-1}.an^{-1})	2330	2741	2393	3147	3211	3378

Table 21 shows the hydrobiological parameters in the ponds. Mean oxygen concentrations in the afternoon were higher in the ponds with the higher water exchange rate. Thus, there is a significant ($p<0.05$) linear relationship ($r^2=0.94$) between mean afternoon D.O. and water renewal rate. Mean morning oxygen concentrations increased significantly ($r^2= 0.76$) as water exchange rate increased. The lowest value observed during the rearing cycle was 1.2 mg.l^{-1} in the pond with the higher water exchange rate. Mean nocturnal D.O. demand (mean of afternoon values minus morning D.O. values) were homogenous ($p<0.05$) and ranged from 2.27 mg.l^{-1} to 2.44 mg.l^{-1}. For all ponds, mean morning and afternoon temperatures were

23.0° C and 25.3° C, respectively. The lowest and highest values were 19° C and 32.3° C. The mean values of pH, measured at 4:00 pm ranged from 8.20 to 8.28 and decreased significantly ($p<0.05$; $r^2=0.69$) as water exchange rate increased. Temperature and pH declined all along the experiment. Salinity values ranged from 30.6 ‰ to 31.5 ‰ and seemed to decrease with the lowest water exchange rate.

Table 21. Means ± standard deviation and range of hydrobiological parameters in the six ponds studied.

Daily renewal rate (%.day^{-1})	10±0.7 pond 1	11±0.8 pond 2	17±1.2 pond 3	17±1.2 pond 4	21±1.5 pond 5	23±1.6 pond 6
Oxygen morning (mg.l^{-1})	5.64±0.80 (2.4-7.5)	5.75±0.82 (2.6-7.1)	5.95±0.76 (3.0-7.7)	5.95±0.74 (2.4-7.4)	6.02±0.72 (2.9-7.4)	5.92±0.81 (1.2-7.6)
oxygen evening (mg.l^{-1})	7.98±0.84 (6-11.6)	8.12±0.76 (6.3-11.5)	8.24±1.04 (5.6-13.1)	8.26±0.85 (6.1-12.6)	8.35±0.83 (6.3-11.6)	8.41±0.74 (6.5-10.6)
Nightly D.O. demand (mg.l^{-1})	2.37±0.81	2.34±0.94	2.27±0.95	2.31±1.0	2.33±0.97	2.45±0.92
pH evening	8.28±0.24 (7.8-8.7)	8.27±0.20 (7.9-8.7)	8.24±0.20 (7.8-8.7)	8.20±0.19 (7.9-8.7)	8.20±0.19 (7.9-8.8)	8.22±0.17 (7.9-8.8)
T°C morning	23.0±2.7 (19-26.9)					
T°C evening	25.3±3.0 (20-32.3)					
Salinity ‰	30.6±2.4 (24-35)	30.8±2.2 (25-35)	30.9±2.3 (24-35)	31.4±2.3 (24-35)	31.2±2.2 (25-36)	31.5±2.4 (25-36)

Each value represents the mean of 198 analyses except for pH, salinity and oxygen evening (n=58).
Temperature measurements were made only in one pond (daily renewal rate: 10 %).

Table 22 shows the concentrations of particulate and dissolved elements and compounds in the inflow and outflow during the rearing period. Comparison of the characteristics of outflow water showed a change ($p<0.05$) in the concentration of sestonic forms. There is an increase of seston in the four ponds with the highest water exchange rate. Mean concentrations in these ponds ranged from 15.2 to 17 mg.l^{-1} while in the others ponds, they ranged from 10.5 to 12.6 mg.l^{-1}. A decrease was observed in the proportion of organic matter present in the suspended solids 5, 6 and 7. Furthermore, there is no significant difference ($P<0.05$) between mean chlorophyll-a, mean organic matter and of mean particulate nitrogen. Mean concentrations of (NH_3-NH_4^+)-N ranged from 6.5 to 11.9 µg.l^{-1}. Mean concentrations of total soluble nitrogen seemed to be higher as water exchange rate was lower and ranged from 370 to 448 µg.l^{-1}. However, there was no significant difference ($P<0.05$) between ponds. As an example of variations of sestonic parameters, **figure 12** shows variations of chlorophyll-a and of particulate nitrogen.

Table 22. Means ± standard deviation and range for chemical and biological outflowing water quality parameters for the six ponds studied.

	Inflow	Outflow					
Daily renewal rate (%.day^{-1})		10±0.7 pond 1	11±0.8 pond 2	17±1.2 pond 3	17±1.2 pond 4	21±1.5 pond 5	23±1.6 pond 6
Particulate							
Seston (mg.l^{-1})	14.7±18.9	12.6±6.8	10.5±5.9	15.2±9.3	16.7±11.4	15.4±8.0	17.0±18.4
	(4.2-142.4)	(5.2-38.3)	(2.8-29.7)	(5.4-39.3)	(5.8-51.2)	(6.4-42.4)	(4.4-115)
Org. Mat. (mg.l^{-1})	3.1±3.1	4.2±1.5	3.8±1.4	4.3±1.6	4.1±1.7	3.9±1.5	4.0±2.4
	(1-22.4)	(1.8-8.6)	(1.2-7.7)	(2.2-9.2)	(2.0-8.8)	(1.8-8.8)	(1.6-16.3)
Org. Mat. (%)	23±6	38±13	42±14	36±16	31±14	29±9.5	32±11
	(8-41)	(19-82)	(18-79)	(8-73)	(14-84)	(9-47)	(14-59)
Chl-a (µg.l^{-1})	5.4±5.3	14.4±6.5	13.6±5.1	14±6.3	13.5±7.3	11.6±5.5	13.6±9.2
	(1.2-31.5)	(0.4-29.8)	(6.0-27.0)	(3.1-31.2)	(0.2-37.0)	(3.3-31.0)	(3.0-53.2)
Pheop. (µg.l^{-1})	1.8±1.5	2.8±3.0	2.3±2.0	2.9±2.0	2.8±1.9	3.1±1.8	2.7±2.3
	(0.5-9.1)	(0-18.1)	(0-10.1)	(0-8.7)	(0-8.9)	(0.7-8.5)	(0-10.2)
Chl-a/org. Mat. (mg.g^{-1})	1.9±1.4	3.6±1.8	3.8±1.4	3.3±1.4	3.3±1.2	3.1±1.4	3.4±1.6
	(0.2-6.6)	(0.1-9.9)	(1.3-7.9)	(1.2-7.5)	(0.1-7.2)	(0.9-8.5)	(1.1-8.5)
N (µg.l^{-1})	149±103	290±89	280±90	303±98	274±104	247±78	272±147
	(62-637)	(176-505)	(153-464)	(147-544)	(137-529)	(177-426)	(151-732)
Dissolved							
(NH_4^+-NH_3)-N (µg.l^{-1})	15.8±13.0	8.2±9.0	7.8±12.9	11.9±20.8	9.0±12.7	6.5±7.5	10.6±12.4
	(0.2-55.6)	(0-49.4)	(0-70.4)	(0-136.1)	(0-72.5)	(0-34.7)	(0-65.2)
Total (soluble)-N (µg.l^{-1})	392±456	448±338	413±158	375±272	395±326	370±312	399±328
	(99-2321)	(46-2453)	(231-1708)	(181-1328)	(144-2122)	(112-2103)	(157-2068)

Each value represents the mean of 58 analyses except for particulate nitrogen (n=32).

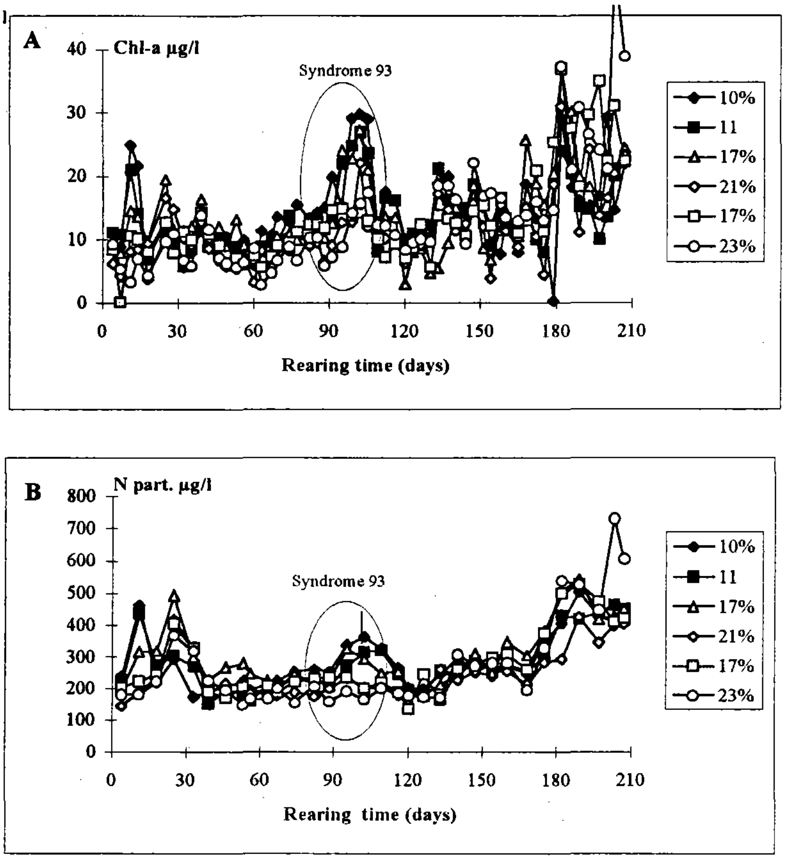


Figure 12. The effect of water exchange rate on evolution of (A) chlorophyll-a concentrations and (B) particulate nitrogen concentrations. The circled data are concomitant with syndrome 93 mortality.

Table 23 shows the sediment characteristics at the beginning and at the end of the rearing period. The quantity of dry sediment « accumulated » on the bottom, during the rearing was calculated with values of elevation of the pond bottom measured on 5 graduated posts, the density, and the water content. It is to be noted that the « accumulation » of sediment is higher in the two ponds with the highest water renewal rate (ponds 5 and 6), than in the other one. For concentrations of organic matter and total nitrogen, there was no significant difference ($p<0.05$) between ponds at the beginning and at the end of the rearing period whatever the water renewal rate. As with sediment quality, we observed for all ponds an increase of the mean concentrations of organic matter and total nitrogen in sediment. For example in pond 10 % renewal rate (pond 1), the mean level of organic matter increased from 5.85±0.12 % to 7.66±0.11 %. In parallel, the concentration of total nitrogen increased from 1.34±0.39 $mg.g^{-1}/dw$ to 2.14±0.28 $mg.g^{-1}/dw$. However, nitrogen enrichment in pond sediment during the rearing period was more important in the two ponds with higher water exchange rate. Thus, the difference between the mean concentration of total nitrogen at the beginning and at the end of the rearing period was 0.8, 0.7, 0.72, 0.79, 1.04 and 0.94 $mg.g^{-1}/dw$. Levels of organic matter (O.M.) were significantly ($p<0.05$) proportional to the concentrations of total nitrogen (O.M. = 0.0259 x N + 0.0205 ; $r^2=0.94$).

Table 23. Sediment characteristics at the beginning and at the end of rearing period.

Daily renewal rate (% day^{-1})	10±0.7 pond 1	11±0.8 pond 2	17±1.2 pond 3	17±1.2 pond 4	21±1.5 pond 5	23±1.6 pond 6
Before rearing						
Density ($g.cm^{-3}$)	2.27±0.24	2.19±0.18	2.26±0.11	2.25±0.08	2.22±0.07	2.21±0.13
Water content (%/dw)	46±17	48±13	41±9	40±7	44±5	45±9
Redox potential (mv)	132±46	105±50	111±42	96±23	127±35	125±48
Organic matter (%/dw)	5.85±0.12	5.52±0.13	4.32±0.12	5.92±0.10	4.89±0.09	5.17±0.08
Total nitrogen ($mg.g^{-1}$/dw)	1.34±0.39	1.28±0.58	0.97±0.38	1.45±0.41	1.11±0.34	1.27±0.30
(NH_4^+-NH_3)-N ($mg.l^{-1}$) Pore water	13.42±2.16	17.25±19.21	6.30±5.66	4.91±4.08	9.26±10.95	6.20±3.28
At the end						
Accumulated layer (dm^3 wet weight)	17415	16524	14652	11495	29773	21929
Density ($g.cm^{-3}$)	1.76±0.17	1.81±0.18	1.86±0.19	1.87±0.30	1.69±0.15	1.84±0.35
Water content (%/dw)	125±44	140±38	107±42	114±62	162±61	124±59
Accumulated dry sediment (kg)	13609	12452	13203	10012	19166	17987
Redox potential (mv)	114±8	114±20	130±19	133±19	135±19	133±20
Organic matter (%/dw)	7.66±0.11	6.83±0.14	6.41±0.09	8.12±0.14	7.28±0.15	8.04±0.17
Total nitrogen ($mg.g^{-1}$/dw)	2.14±0.28	1.98±0.52	1.69±0.38	2.24±0.51	2.15±0.64	2.21±0.63
(NH_4^+-NH_3)-N ($mg.l^{-1}$) Pore water	1.05±0.69	1.43±1.73	2.88±3.54	0.78±0.24	1.38±1.99	0.80±0.35

Each value corresponds to the mean of 5 measurements made in each pond.

Water content increased in all the ponds, as well as the density decreased. The mean concentration of (NH_3-NH_4^+)-N in pore water decreased during the rearing period. Before rearing the concentrations ranged from 6.2 to 17.25 $mg.l^{-1}$ depending on the pond, while after rearing they ranged from 0.78 to 2.88 $mg.l^{-1}$. There is no evidence of any correlation between water renewal rate and the concentration of (NH_3-NH_4^+)-N in pore water.

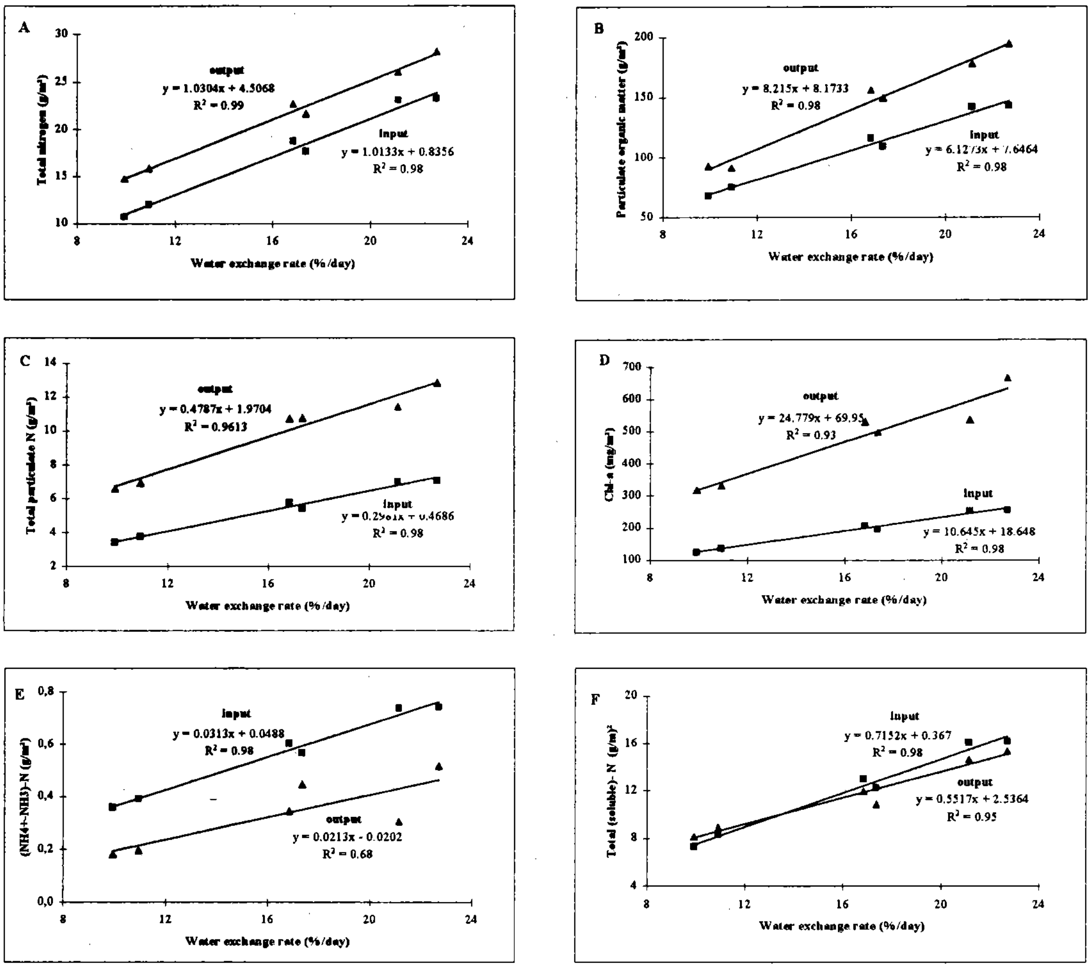


Figure 13.Relationships between amount of particulate and soluble element output in the outflow and in the inflow and water exchange rate.

Amounts of particulate and soluble elements in the inflow and outflow were investigated in relation to water exchange rate (**figure 13**). Daily concentrations were multiplied by water volumes to get the total mass of each parameter. Values for each parameters were integrated between two samplings and summed for the season. Results were extrapolated (adjusted and averaged) to the pond surface area ($g.m^{-2}$). We observed (**fig. 13a**) an increase ($p<0.05$) in both input and output of total nitrogen. The difference between the output and the input was similar whatever pond studied. Values ranged from 2.99 to 4.99 $g.m^{-2}$ (**table 21**, line I) and did not change ($p<0.05$) with an increase in water exchange rate. Amounts of exported particulate organic matter (**fig. 13b**) and exported N-particulate forms (**fig. 13c**) increased ($p<0.05$) in both inflow and outflow with higher water exchange rate. However, the budget of particulate organic matter and N-particulate forms (output minus input) increased ($p<0.05$) with water exchange rate. The budgets of chlorophyll-a (**fig. 13d**) increased ($p<0.05$) in the same way. As for soluble elements, total exported ammonia nitrogen (**fig. 13e**) and total exported soluble nitrogen (**fig. 13f**) increased ($p<0.05$) with water exchange rate. Exports of total ammonia nitrogen were lower than imports. The budget was not significantly ($p<0.05$) correlated with an increase in water exchange rate. Exports of total soluble nitrogen were lower than imports in the 4 ponds and nearly equal to zero in the 2 other ponds. Budgets decreased ($p<0.05$) with an increase in water exchange rate.

The results suggested that increasing water exchange rates boosted primary production. Therefore, compounds produced by mineralisation and metabolism of organic matter (feces, uneaten feed) were exported as particulate rather than soluble matter. Nitrogen exports minus nitrogen imports in the six ponds appear similar (**table 24**, line I). Mean water enrichments in nitrogenous compounds while passing through the pond were respectively 35 % (ponds 1 and 2), 22 % (ponds 3 and 4), and 17 % (ponds 5 and 6) with increasing water exchange rate.

Table 24. Water renewal rate. Nitrogen budgets in the earthen ponds[a].

Daily renewal rate (% day^{-1})	10±0.7 pond 1	11±0.8 pond 2	17±1.2 pond 3	17±1.2 pond 4	21±1.5 pond 5	23±1.6 pond 6
A Pond surface (m^2)	1370	1520	1450	1450	1460	1520
B Harvest (Kg Wet Weight)	182.8	238.6	198.7	266.6	263.1	294.0
C Feed pellets-N ($kg.ponds^{-1}$)	33.5	39.0	36.8	40	42	45.1
D Shrimp harvested-N ($kg.ponds^{-1}$)	5.90	7.70	6.41	8.60	8.49	9.48
E Feed efficiency-N (%)	17.6	19.7	17.4	21.5	20.2	21.0
F Total waste-N ($kg.ponds^{-1}$)	27.6	31.3	30.4	31.4	33.6	35.6
G Waste-N ($g.kg^{-1}$ shrimp harvested)	150.8	131.1	153.1	117.8	127.5	121.1
H Total waste-N ($g.m^{-2}$)	20.1	20.6	21.0	21.7	23.0	23.4
I Waste in outflow water-N ($g.m^{-2}$)	4.00	3.83	3.96	3.95	2.99	4.99
J Waste-N in sédim.+atmos. ($g.m^{-2}$)	16.12	16.75	17.02	17.71	19.99	18.43
Input-N ($g.m^{-2}$)						
K Water-N (dissolved + particulate)[b]	10.7 (30)	12.0 (32)	17.6 (41)	18.7 (40)	23.1 (44)	23.2 (44)
L Feed pellets-N[b]	24.4 (70)	25.6 (68)	25.4 (59)	27.6 (60)	28.8 (56)	29.7 (56)
M Total input-N	35.1	37.6	43.0	46.3	51.8	52.9
Output-N ($g.m^{-2}$)						
N Water-N (dissolved + particulate)[b]	14.7 (41.9)	15.8 (42.0)	21.6 (50.2)	22.7 (49.0)	26.0 (50.2)	28.2 (53.3)
O Shrimp-N[b]	4.3 (12.3)	5.1 (13.6)	4.4 (10.2)	5.9 (12.7)	5.8 (11.2)	6.2 (11.7)
P N in excess in sediment[b]	7.9 (22.4)	5.7 (15.2)	5.5 (12.8)	5.4 (11.7)	13.7 (26.5)	11.2 (21.2)
Q N to atmosphere[b]	8.2 (23.5)	11.0 (29.3)	11.5 (26.7)	12.3 (26.6)	6.3 (12.2)	7.3 (13.8)

[a] The different compartments of nitrogen were calculated as follow: line C = N concentration in feed x total weight of feed ; Line D = N concentration in shrimp x weigh of shrimp harvested ; Line E = (D/C) x 100 ; Line F = C-D ; Line G = F/B ; Line H = F/A ; Line I = (total nitrogen in outflow)-(total nitrogen in inflow) ; Line J = H-I ; Line K = (nitrogen concentration in inflow water x volume of inflow)/A ; Line L = C/A ; Line M = K+L ; Line N = (nitrogen concentration in outflow water x volume of outflow)/A see text, Line O = D/A ; Line P = (N concentration in sediment at the beginning - N concentration in sediment at the end of the rearing period) x volume of the sediment accumulated ; Line Q = M-(N+O+P).
[b] Between brackets is expressed the percentage of the compartment versus total input-N (line M).

Table 24 shows the nitrogen budgets. Nitrogen entering the ponds through inflowing water and feed pellets follows several pathways. It can be used by shrimp to build up proteins, exported in effluent water, accumulated in the sediment and released into the atmosphere, through diffusion or denitrification. In order to determine the amount of nitrogen entering the sediment during the rearing period, we calculated the extra amount of nitrogen in the sediment accumulated on top of the original level of the pond bottom (**table 23**). Extra nitrogen in the sediment of each pond was estimated, taking into account the difference between the nitrogen concentration at the end of the experiment with the concentration at the beginning, the volume of accumulated sediment, the mean density of the sediment and the mean water content of the sediment. The nitrogen concentration in feed pellets and in shrimp, determined in 10 samples was respectively 70.1±1.1 and 32.2±4.6 $mg.g^{-1}$ wet weight.

The proportion of feed pellet-N used by the shrimp is shown in **table 24**, line E. It was slightly higher in ponds with higher water exchange rate and so was the amount of wastes. The amount of exported wastes in the outflow was similar ($p<0.05$) for all ponds (**table 24**, line I). This led to an accumulation of wastes in the sediment and atmosphere (**table 24**, line J) slightly higher ($p<0.05$) for those ponds with high water exchange rate ($y=13.98+0.224x$; $r^2=0.70$). However, we found that the amount of nitrogen entering the sediment (**table 24**, line P) was more important in the two ponds with highest water exchange rate (13.7 and 11.2 $g.m^{-2}$ for ponds 5 and 6 respectively) than in the four other ponds (5.4 to 7.9 $g.m^{-2}$). Therefore, it seemed that the amount of nitrogenous wastes was the same, no matter the water exchange rate, but followed different pathways afterwards. In all cases of water exchange, the part of nitrogen discharged by outflow represents the largest quantity, 41.9 to 53.3 %, of nitrogen which is entering the ponds. The part of nitrogen which is converted into shrimp is quite stable from one pond to another (11.7 to 13.6 %). Differences observed in nitrogen budgets regard mainly both sediment and atmosphere compartments. In ponds with a low water exchange rate (ponds 1 to 4) nitrogen discharged to the atmosphere represents 23.5 to 29.3 % of total nitrogen input. For ponds with 21 and 23 % water exchange rate (ponds 5 and 6) only 12.2 and 13.8 % respectively are discharged to the atmosphere. These ponds 5 and 6 with a higher water exchange rate show the highest rates of nitrogen accumulation in the sediment (26.5 and 21.2 % respectively).

Table 25 shows the fate of feed-N in the different compartments. There is a slight increase in Feed-N utilisation by the shrimp with increasing water renewal rate, from 17.6 % to 20.9 % for water renewal ranging from 10 %.d-1 to 23 % d^{-1} (ponds 1 to 4). In the mean time, the stocking of nitrogen in the sediment increased. The highest values, 47.6 and 37.7 %, are shown in ponds with highest water renewal rate, 21 and 23 % respectively (ponds 5 and 6).On the contrary, the discharge to atmosphere (diffusion and denitrification) is higher in the ponds showing the lowest water renewal rates. It ranges from 33.6 to 45.3 % in ponds with 10 to 17 % water renewal rate (ponds 1 to 4).

Table 25. Fate of Feed-N in rearing ponds: influence of water renewal rate in earthen ponds.

Water renewal (%)	Stocking density ((biomass	% in shrimp	% in outflow	% in sediment	% to atmosp.
10 (pond 1)	20	17.6	16.4	32.4	33.6
11 (pond 2)	20	19.9	14.8	22.3	43.0
17 (pond 3)	20	17.3	15.7	21.7	45.3
17 (pond 4)	20	21.4	14.5	19.6	44.6
21 (pond 5)	20	20.1	10.1	47.6	21.9
23 (pond 6)	20	20.9	16.8	37.7	24.6

1.2.3.2.1.3. Discussion

It has been shown that there is an increase in the mortality, with a decrease of the water exchange rate. As a general rule, a decrease in water exchange does not lead to a drop of survival. This topic has been the focus of many studies. Hopkins *et al.* (1991) came up to that conclusion in an experiment with grow-out ponds stocked with *Penaeus vannamei* at 76 animals.m^{-2}. Water exchange rates were respectively 4 % (low water exchange) and 14 % (standard water exchange) per day. Similarly in 1993, the same authors showed that survival at harvest was not influenced by greater water exchange. Another study carried out in New-Caledonia in semi-intensive conditions (12 animals per m^2) showed no significant difference in survival (79 % to 81 %) with a mean harvest weight between 20.8g and 23g (Goxe, 1988).

Our study pointed out a drop of survival associated with a decrease in water exchange rates. This survival drop could be the result of a mortality peak that occurred after 80 days of grow-out. This phenomenon of mortality, called « syndrome 93 » described by several authors (Berthe *et al.*, 1995 ; Costa *et al.*, 1996a ; 1996b ; Goarant *et al.*, 1996 ; Legroumellec *et al.*, 1996a ; 1996b ; 1996c ; Mermoud *et al.*, 1996a ; 1996b) showed up in all grow-out farms in New-Caledonia in 1993. This epizootic is characterised by short outbreaks essentially at both ends of the cold season. The histological table is one of a standard septicemic vibriosis. Pathogenic vibrio strains have been isolated (*Vibrio penaecidae* and *Vibrio nigripulchritudo*) and it appeared that the disease was contagious and carried up by water (Goarant, personal communication). New-Caledonian farms yields are, at the moment, clearly higher in hot season than in cold season depending on stocking time (Pham *et al.*, 1997). In 1993, Tuckers *et al.* showed that seasonality had a significant effect on pond water quality. In New-Caledonia, running of the pond ecosystem depends on climatic factors. Inadequate conditions (low temperatures, short period of sunshine) induce a low phytoplanctonic biomass in the rearing environment and thus a poor quality water whatever pond management practices. The disease called « Syndrome 93 », outbreak at the start of the cold season is concomitant to the set up of this kind of rearing environment. However, an increase in water exchange in the pond restricted the disease impact on the crop. As a matter of fact, the mortality was decreased in the ponds with the highest water renewal rate. Zootechnical management has already been questioned during the development of diseases (Flegel *et al.*, 1995), and it is to be noticed that Baticados *et al.* (1986) observed an important spread of chronic soft-shell syndrome in *Penaeus monodon* in ponds with insufficient water exchange. Nevertheless, the direct influence of water renewal on the outbreak and spreading of the disease is not yet established.

According to the literature, growth rate is not affected by different water exchange management strategies (Hopkins *et al.*, 1991 ; 1993). Mean weight differences between ponds at harvest could be explained by a density effect after an episode of «syndrome 93»-related mortalities. Indeed, densities in grow-out ponds are different after a peak of mortality. Several studies have already demonstrated a reverse relationship between grow-out densities and growth (Ray and Chien, 1992 ; Lee *et al.*, 1986 ; Daniels *et al.*, 1995 ; Sandifer *et al.*, 1987 ; Martin *et al.*, in press). This difference showing-up in the grow-out phase may account for the final weight difference. Water exchange rate would have an influence on final survival and consequently final mean weight. Thus, there is a significant ($p<0.05$) linear relationship ($r=0.95$) between survival and final mean weight.

In this study, the deterioration of the FCR with water exchange rate can be related either to a progressive overfeeding du to mortalities (as a matter of fact, the evaluation of survival and, as a consequence the feeting of feed ration cannot be immediately evaluated in earthen ponds with phytoplanktonic bloom) or to a drop in the contribution of primary production to the shrimp nutrition or. Cam *et al.* (1991) showed that in semi-intensive conditions, compounded diets play a limited nutritional role in the first weeks of grow-out of *Penaeus japonicus* , their importance gradually increasing to becoming essential later on. Reymond and Lagardère (1990) found that despite a daily supply of pelleted food, naturally occurring preys were the largest food source for *Penaeus japonicus* (density from 10 shrimp.m^{-2} at stocking to 3.4 shrimp.m^{-2} at harvest). Although a decrease in the contribution of «natural food» with a density increase has been shown (Maguire *et al.*, 1983), to our knowledge no study has indicated an influence from water exchange rates. Decreased survival have more likely affected nutrition rate. Thus, progressive overfeeding subsequent to an overestimate of survival along the experiment and a shrimp biomass loss during the mortality peak can both account for the FCR increase with water exchange rate.

Although dilution of the water column was beneficial to the crop health at the start of the cold season, increasing water exchange rate did not bring a significant change in the average quality of the rearing environment along the whole grow-out period. Morning DO concentrations were always well above lethal thresholds. Lethal DO concentrations for *Penaeus monodon* vary from 0.5 to 1.2 mg.l^{-1} depending on time of exposure (Chamberlain, 1988). *Penaeus japonicus* shows signs of stress with DO concentrations as high as 1.4 mg.l^{-1} (Egusa, 1961). In our study, minimum DO concentration was 1.2 mg.l^{-1} in ponds with highest water exchange rate at the end of the experiment. This was an exceptionally low morning value but no particular mortality was recorded. Critical DO levels for normal growth are reported to be between 1.2 to 1.9 mg.l^{-1} for *Penaeus vannamei* (Seidman *et al.*, 1985) and 1.2 to 2.2 mg.l^{-1} for *Penaeus monodon* (Allen *et al.*, 1991). According to Fast *et al.* (1992), DO concentrations for «normal» growth are probably 3.7 mg.l^{-1} or higher which is confirmed by Lawrence (1995) who recommended 3.5 to 4 mg.l^{-1} or more for *Penaeus stylirostris.* Oxygen concentrations did not seem to have an effect on growth in this experiment as shrimp exposure time to low oxygen values (<3.5 mg.l^{-1}) was very short. Altogether, there was a maximum of four O_2 values lower than 3.5 mg.l^{-1} at 6:00 am witch were susceptible to influence growth according to the literature cited above. Therefore it seems that O_2 concentrations had little or no effect at all on shrimp survival and growth. However we found a slight increase of morning and afternoon O_2 levels associated with an increase of water exchange rate.

pH measurements at 4:00 pm varied according to the period of sunshine and phytoplancton abundance. A decrease of water exchange rate gave a pH increase with mean values from 8.20 to 8.28 which although significant showed only a slight influence of water exchange rate on pH. A strong pH brings up the proportion of ammonia (NH_3), in the NH_3-NH_4+ equilibrium, which is the most toxic nitrogenous compound for animals (Colt and Armstrong, 1981). In this study however, it was not possible to analyse ammonia toxicity as nitrogen-related measurements were taken in the morning and pH in the evening. However it is important to note that ammonia mean concentrations in the pond water column were always very low and in any case lower than levels in pumped water whatever water exchange rate. Maintaining an active primary production in ponds will effectively eliminate ammonia as soon as it is produced from organic wastes and thus will not give it time to get toxic for the crop. All ponds together, the highest pH value was 8.8 at the start of the experiment. According to Tsai (1990) lethal levels thresholds for Penaeidea are respectively 4.8 and 10.6 with optimum growth between 6.6 and 8.5. The up limit (8.5) defined above was rarely exceeded in this study and as no measurement was taken in the morning, the low limit could not be determined.

There was no significant difference between means for the main compounds measured in the pond outlets. Mean concentrations of chlorophyll-a, pheopigments, particulate organic matter, particulate nitrogen, total soluble nitrogen and ammonia could be considered similar whatever water exchange rate. For example, chlorophyll-a mean concentrations vary from 11.6±5.5 to 14.4±6.5 µg.l^{-1} at an initial density of 20 animals.m^{-2}. On the contrary, an experiment carried out over nine weeks by Allan *et al.* (1993) on the effect of water exchange rate on pond water quality showed an increase of chlorophyll-a level (from 16.9 to 62.4 $\mu g.l^{-1}$) with a decrease of water exchange rate (from 40 to 0 % per day) at 20 $shrimp.m^{-2}$. Hopkins *et al.* (1993) also showed a change in water quality with an increase of water exchange rate. They found a significant increase of phytoplancton biomass through an increase of *in vivo* fluorescence. They also found a significant increase in the concentration of different nitrogenous compounds (total ammonia, unionised ammonia-N, nitrates, nitrites and total nitrogen) with a decrease of water exchange rates along with a decrease of particulate organic matter. Our results are therefore not typical to what can be found in the literature. The season factor is relatively important in New-Caledonia as water temperatures range between 19° C and 25° C in cold season and between 27° C and 32° C in summer. Transition periods are relatively short, from 15 days to 1 month. The absence of significant effect of density or water exchange rate on phytoplancton biomass might be explained by low temperatures and the shortening of the hours of sunshine. The phytoplancton plays a central role in the maintenance of water quality by regulating nutrient concentrations, oxygen levels, pH, turbidity, bacterial abundance and zooplankton biomass (Chien, 1992).

A shortening of the hours of sunshine in cold season is a limiting factor for phytoplankton growth in shrimp ponds (Burford, 1997). Tucker *et al.* (1993) suggested that light was the most important variable in the control of phytoplankton abundance in Mississippi Channel Catfish rearing. The break-down of accumulated organic matter during the rearing period (feed left-overs, dead phytoplankton, excretory wastes) is dependent on temperature and could then be slowed down in cold season. In particular, nitrogenous compounds from this recycled organic matter normally sustain primary production (Herbland, 1975). A drop of turn-over would lead to a decrease of the pond primary production. Similarly, Boyd (1983) concluded to a relative efficiency of water exchange on the biological processes and the organic matter cycle under certain conditions. It would depend on climatic conditions.

Supplementary feeding lead to an organic matter enrichment of the sediment which affect its quality and subsequently the pond economic viability (Avnimelech, 1980). Sediment quality is considered as an essential rearing success factor (Chamberlain, 1988 ; Hussenot and Feuillet-Girard, 1988 ; Boyd, 1991 ; 1992 ; Peterson and Daniels, 1992). The effect of some zootechnical practices on sediment enrichment with organic matter as been tested by many authors. This enrichment gets more important in more intensive systems (Hussenot *et al.*, 1988 ; Martin *et al.*, in press). Aeration improves the proportion of remineralisation of organic matter in the sediment (Avnimelech *et al.*, 1992) and globally, the build up of organic matter with time, is less important in aerated than in unaerated ponds (Ghost, 1981 ; Ayud *et al.*, 1994). However few authors have studied the effect of water exchange rates on the sediment. In our study, if an accumulation of organic matter and nitrogen in the sediments was found between the start and the end of the rearing period, this accumulation is not influenced by the rate of water renewal, comprised between 10 and 23 %.

Accumulation of dry material (up to 19166 kg) on the pond bottom cannot be caused only by the inputs of feed and of suspended matter brought in by inflowing exchange water. Rising of sediment level could be attributed to two reasons: the dike erosion and the sediment emulsion caused by shrimp swimming. Larger deposition are actually observed in ponds with, simultaneously, higher water exchange rates and higher survival rates (ponds 5 and 6).

Data collected in this experiment indicated that the amount of wastes exported with outflow increased with water exchange rates. Furthermore, increasing water exchange also leads to an increased import of soluble and/or particulate organic matter and minerals.

The amount of nitrogen exported with outflow increased from 14.7 to 28.2 $g.m^{-2}$ depending on water exchange rates. This is directly linked to the increase of imported nitrogen from 10.7 to 23.2 $g.m^{-2}$ in the exchanging water. Indeed, the balance between exported amounts minus imported ones did not show a better nitrogenous wastes removal with an increase of water exchange rates. Exported amounts were similar to the data presented by Briggs *et al.* (1994) for an intensive system in Thailand. They varied from 13.45 to 22.28 $g.m^{-2}$ per production cycle. Imported amounts were however lower in that study, ranging from 3.5 to 4.4 $g.m^{-2}$ per cycle. Therefore in this study we obtained balance sheets in water (exports minus imports) between 3 and 5 $g.m^{-2}$ while in semi-intensive conditions (50 to 60 $shrimp.m^{-2}$ at stocking) they vary from 10 to 18 $g.m^{-2}$ per cycle (Briggs *et al.*, 1994). This difference might be explained by a density effect. Martin *et al.* (in press) have shown an increase of the nitrogenous balance sheet with density (1 to 30 $shrimp.m^{-2}$ at stocking) with values rising from 2.0 to 5.9 $g.m^{-2}$.

These balance sheets showed that the wastes origin changes with an increase of water exchange rate. Organic forms originate from the metabolism of organisms and break-down of organic matter (Hirayama *et al.*, 1988 ; Wickins, 1985). Mineral forms (NH_{3-4}^{+}, NO_2^-, NO_3^-) are produced from organic wastes accumulated in the sediment (Blackburn *et al.*, 1988). The ammonia form can also be excreted by shrimp (Wajsbrot *et al.*, 1989). These minerals are used for primary production and phytoplankton growth or removed by volatilisation (Veiler, 1979). There was no nitrates and nitrites analysis in this study. These compounds mean concentration over a rearing period are usually extremely low in the pond effluents and have been considered negligible to the mean concentration of total soluble nitrogen. Moreover they are in average, always much lower than ammonia mean concentration (Martin *et al.*, in press). In this work, the ammonia represented a mean maximum of 3.1 % of total nitrogen. It was therefore possible to estimate that total soluble nitrogen was in fact made of 95 % organic soluble nitrogen and that organic forms made up the main body of soluble nitrogenous wastes.

Balance sheets for soluble nitrogenous forms (total soluble nitrogen and ammonia) were inversely proportional to water exchange rates. Therefore an increase of the latter would allow a better recycling of mineral nutrients and soluble organic compounds. Balance sheets for ammonia were respectively <0 and <0 or equal to 0 of total soluble nitrogen. This means that imports were greater than or equal to exports. Although unlikely, the main risks for the environment which gets the wastes are mainly to do with nutritive salts discharge which can cause an eutrophication problem (Pillay, 1992). These results which have already been suggested (Lemonnier *et al.*, 1996) showed that increasing water exchange rates led to a rise of primary production and an increase of wastes exports in particulate rather than soluble forms. However it did not increase wastes export originating from the crop.

The majority of incoming and outgoing nitrogen sources has been assessed in order to study the main flows of matter in the system. The main incoming ones are feed and exchanging water. The more important nitrogen import is the former, making up between 56 and 70 % of total import. It is possible to evaluate the proportion of assimilated feed-N in the shrimp tissues with the amount of feed-N that has been given. In this study, it ranged from 17.4 to 21.5 %. Briggs *et al.* (1994) estimated the nitrogen retention rate at 23 %. He pointed out that this rate was relatively low compare to the ones seen in cultured marine fishes (20 to 50 %). He attributed this difference to the animals feeding behaviour.

Other nitrogen sources could be considered negligible and as such have not been assessed in detail. This was the case of inorganic nitrogen from rainfalls. For example, using the data from the National Weather Forecast, water from rainfalls made up a maximum of 3.3 % of total water import in the pond with the lowest water exchange rate. Mineral nitrogen levels may be important in rainfall waters from heavily industrialised area, which is not the case in our study.

Hopkins *et al.* (1993) estimated rainfall nitrogen at less than 1% of total nitrogen imports for a rearing period of 148 days in a pond stocked at 44 shrimp.m^{-2} and a mean water exchange rate of 25 %. Another incoming nitrogen source comes from atmospheric nitrogen fixation by some algae (Sournia, 1968). So far, it has not been assessed in any nitrogen balance sheets in farmed shrimp and always been considered negligible by several authors (Boyd *et al.*, 1989 ; Hopkins *et al.*, 1993 ; Martin *et al.*, in press ; Briggs *et al.*, 1994). Stocked post-larvae are also an incoming nitrogen source which has been neglected. According to Briggs *et al.*, it makes up 0.01 % of nitrogen import.

The fate of the different incoming nitrogenous sources encompassed 4 compartments: exported nitrogen in the effluents, accumulated nitrogen in the sediments, discharged nitrogen to the atmosphere and nitrogen used by shrimp. The rate of nitrogen used by shrimp is relatively low whatever the water exchange rate. The proportion to total incoming nitrogen ranged from 10.2 to 13.6 %. In other experiments, it ranged from 12 to 25 % for Martin *et al.* (1996), from 20 to 22 % for Briggs *et al.* (1994) and was less than 5 % for Hopkins *et al.* (1993).

In the experiment carried out by Briggs *et al.* (1994), nitrogen export by the effluents was 35 % of imported nitrogen while in our study, it represented 41.9 to 53.3 %. It is important to underline that exported nitrogen mainly originates directly or indirectly from nitrogen brought in by water exchange. Water enrichment in nitrogenous compounds while passing through the pond range from 35 to 17 % depending on water exchange rates.

The proportion of nitrogen accumulating in the sediment was estimated between 11.7 and 26.5 % of total nitrogen. The accumulation process is more important in the sediment of ponds with high water exchange rates. Briggs *et al.* (1994) estimated that proportion at 31 % and Martin *et al.* (in press) between 16 and 38 % which was more important with increasing stocking densities.

A proportion of nitrogen imported by water and feed was not found back when assessing balance sheets in the four ponds with the least water exchange. This loss is assessed to represent the discharge of nitrogen to the atmosphere, du to denitrification and diffusion process (Briggs and Funge-Smith, 1994 ; Funge-Smith and Briggs, 1996 ; Hopkins et al, 1993 ; Veiler, 1979). This loss ranged from 12.2 to 29.3 % of total imported nitrogen. The lowest values are shown for ponds with highest water renewal rate (ponds 5 and 6). Hopkins *et al.* (1993) observed a nitrogen loss of 15.7 % of total nitrogen (feed + water exchange) for crops stocked at 44 shrimp.m^{-2} with 25 % water exchange per day. For crops at the same density but with lower water exchange rate (2.5 % and 0 % per day), the loss went up to 43 and 46 % of imports. Thus, in both studies the part of nitrogen discharged to atmosphere was more important in ponds with low water exchange rate. Daniels and Boyd (1989) did not find back 55 % of imported nitrogen in their budgets that is to say an estimated loss of 55 kg. ha^{-1}.production cycle^{-1} (4 months). Boyd (1989) reported a 57 % loss in Channel Catfish culture while Martin *et al.* (in press) observed as well a nitrogen loss of 10 to 32 % of total nitrogen in shrimp culture. While Schroeder (1987) estimated this loss at 50 mg.m^{-2}.day^{-1} nitrogen, it could reach up to 100 mg.m^{-2}.day^{-1} in eutrophic coastal sediments (Knowles, 1982). Gouleau *et al.* (1996) showed a denitrification rate between 2.79 and 9.61 mg.m^{-2}.day^{-1}. Discharge to atmosphere in this study may represent up to 12.3 g.m^{-2} which corresponds to a denitrification and/or diffusion rate of 58.8 mg.m^{-2}.day^{-1}. This data confirmed the results of Martin *et al.* (in press) on the same experimental site. These authors estimated that exported nitrogen in the atmosphere over a rearing period represented in average between 7.7 and 54.1 mg.m^{-2}.day^{-1} according to the stocking density of rearing. For the highest renewal rate, 21 and 23 % (ponds 5 and 6), diffusion and/or denitrification, is lower than for other ponds. Hopkins *et al.* (1993) show a similar result, that is to say an increasing nitrogen loss through atmosphere when water exchange rate decrease. In the state of our knowledge, no explanation can be given to that fact.

1.2.3.2.2. For intensive rearing

1.2.3.2.2.1. Specific characteristics of this experiment

Six experimental cultures were carried out in 13 m^2 outdoors ponds and six exchange rates were tested: 0, 5, 10, 20, 30 and 40 $\%.day^{-1}$. Initial shrimp load was fixed at 319 g m^{-2} in all cultures, corresponding to 86 $shrimp.m^{-2}$. The feeding rate was 21.0 to 21.2 $g.m^{-2}.d^{-1}$ feed pellets. Cultures lasted 34 days. Sludge was collected at harvest. Water compounds were monitored during culture as previously described (see paragraph **1-2-3-1-2-1**). Stocking data are given in **table 26**

Table 26. Effect of water exchange rate. Stocking and harvest data.

Water exchange ($\%.day^{-1}$)	0 %	5 %	10 %	20 %	30 %	40 %
Surface of pond (m^2)	13	13	13	13	13	13
Stocking density (shrimp.m-^{2})	86	86	86	86	86	86
Initial mean weight[a] (g)	3,7	3,7	3,7	3,7	3,7	3,7
Initial biomass (kg)	4,2	4,2	4,2	4,2	4,2	4,2
Duration of culture (day)	34	34	34	34	34	34
Survival rate (%)	67	83	76	74	75	80
Growth rate ($g.day^{-1}$)	0,150	0,168	0,179	0,182	0,179	0,177
F.C. R[b]	3,7	2,0	2,2	2,3	2,3	2,0
Final density (shrimp.m-2)	58	71	66	63	64	69
Final biomass (kg)	6,7	8,7	8,4	8,2	8,2	8,7
Final weight[a] (g)	8,8	9,4	9,8	9,9	9,8	9,7
Total feed in pond (kg)	9,3	9,3	9,3	9,4	9,4	9,3
Production ($g.\ m^{-2}.j^{-1}$)	6	10	10	9	9	10

[a] Mean of 30 shrimp ± standard deviation.
[b] FCR = Food Conversion Ratio.

1.2.3.2.2.2. Results

Table 26 shows technical performances. Survival is 67 % for the 0 % exchange and ranges between 75 and 83 % in the other cultures. Growth rate is lower in the 0 % exchange (0.150 $g.day^{-1}$) than in the other ones (from 0.168 to 1.82 $g.day^{-1}$). FCR is established at 3.7 in the 0% exchange and between 2.0 and 2.3 in the other cultures. Shrimp production is also 6 $g.m^{-2}$.day-1 for 0 % compared to 9 to 10 $g.m^{-2}.day^{-1}$ for the other water exchange rates. Performance obtained are typical of routine intensive culture except for the 0 % exchange treatment.
Variations of hydrobiological parameters are given in **table 27**. It appears that there was no difference between treatments in that experiment, regarding dissolved oxygen, temperature, pH and salinity. Oxygen concentrations ranged from 6.2±0.3 to 5.5±0.4 $mg.l^{-1}$. Like previous experiments in concrete ponds, i.e. concerning the effects of stocking densities (see **paragraph 1-2-3-1-2-1**), air diffusion in the ponds was performed during 22 hours per day.

Table 27. Effect of water exchange rate. Variations of hydrobiological parameters in the ponds. Results are expressed as means ± standard deviations. Between brackets are lowest and highest values.

Water exchange (%.day^{-1})	inflow	0 %	5 %	10 %	20 %	30 %	40 %
Oxygen morning	6,2 ± 0,3	6,4 ± 0,4	6,5 ± 0,3	6,4 ± 0,3	6,3 ± 0,3	6,5 ± 0,4	6,5 ± 0,4
(mg.l^{-1})	(5.8-7.3)	(5.8-7.7)	(6.2-7.7)	(6.0-7.7)	(6.1-7.7)	(6.0-7.6)	(6.1-7.7)
Oxygen evening	6,2 ± 0,3	6,3 ± 0,3	6,3 ± 0,3	6,4 ± 0,3	6,3 ± 0,3	6,4 ± 0,3	6,4 ± 0,3
(mg.l^{-1})	(5.9-7.2)	(5.7-6.8)	(5.8-7.1)	(5.9-7.5)	(5.8-7.1)	(5.9-7.4)	(5.8-7.6)
pH morning	8,1 ± 0,1	7,7 ± 0,1	7,8 ± 0,1	7,8 ± 0,2	7,8 ± 0,1	7,9 ± 0,3	7,9 ± 0,1
	(7.7-8.3)	(7.4-7.9)	(7.4-8.1)	(7.4-8.3)	(7.4-8.0)	(7.5-8.2)	(7.6-8.2)
pH evening	8,0 ± 0,2	8,0 ± 0,2	8,0 ± 0,3	8,1 ± 0,4	8,1 ± 0,2	8,2 ± 0,3	8,2 ± 0,3
	(6.9-8.4)	(7.3-8.3)	(7.1-8.6)	(7.2-8.9)	(7.3-8.6)	(7.4-8.9)	(7.4-8.9)
Temperature morning	28,2 ± 0,4	26,7 ± 0,8	26,8 ± 0,8	26,9 ± 0,8	27,0 ± 0,7	26,9 ± 0,7	26,9 ± 0,8
(°C)	(27.6-29.2)	(25.0-29.0)	(25.0-29.0)	(25.0-29.4)	(25.5-29.0)	(25.2-29.2)	(25.1-29.4)
Temperature evening	28,7 ± 0,5	28,2 ± 0,9	28,3 ± 0,8	28,6 ± 0,9	28,6 ± 0,8	28,6 ± 0,9	28,6 ± 0,8
(°C)	(28.0-29.7)	(26.5-30.2)	(26.2-30.2)	(26.8-30.4)	(27.0-30.3)	(26.8-30.2)	(27.0-30.2)
Salinity (ppt)	35.1 ± 0,3	35,7 ± 0,3	35,7 ± 0,3	35,7 ± 0,3	35.5 ± 0,..	35.4 ± 0,2	35.4 ± 0,2
	(34.5-35.5)	(35.5-36.0)	(35.5-36.0)	(35.5-36.0)	(35.5-.5.5)	(35.0-35.5)	(35.0-35.5)

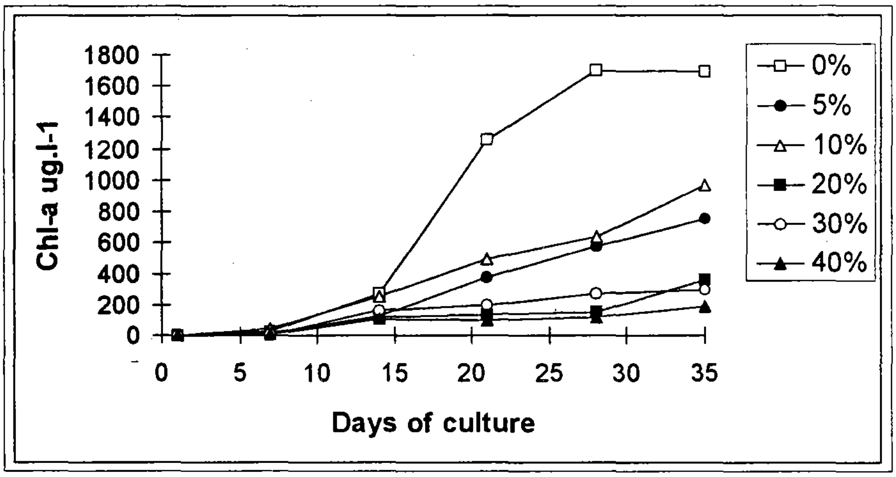
Compounds average concentrations of in-flowing and out-flowing waters are given in **table 28**. Concentrations of all parameters show the same trend for the six treatments. A clear effect of water exchange rate appears: the lower the exchange rate is, the higher the parameter concentration. For total suspended matter, mean concentrations in inflow water is 13.8 ± 6.4, while in outflow water, it decreases from 127.3 ± 99.3 to 42.0 ± 17.0, while water renewal rate increases

.

Table 28. Effect of water exchange rate. Concentrations of main water quality parameters in inflowing and outflowing water. Results are expressed as mean ± SD. Ranges are shown between brackets.

	Inflow	Outflow					
Water exchange (%.day^{-1})		0 %	5 %	10 %	20 %	30 %	40 %
Particulate							
Total Susp. matter (mg.l^{-1})	13.8 ± 6,4	127.3 ± 99,3 (12.4-285.9)	79.5 ± 47,8 (12.0-157.8)	80.3 ± 45,9 (10.7-145.6)	51.7 ± 25,4 (11.8-84.4)	49.7 ± 22,6 (9.2-80.7)	42.0 ± 17,0 (9.9-64.5)
Organic matter (mg.l^{-1})	6.8 ± 5,2	100.0 ± 81,8 (7.6-238.7)	58.4 ± 38,0 (3.1-117.7)	59.1 ± 37,8 (3.4-123.6)	36.4 ± 20,6 (3.0-64.7)	35.5 ± 18,1 (2.5-59.5)	29.2 ± 14,4 (3.3-48.7)
Organic matter (% TSM)	45 ± 14	73 ± 9 (55-84)	68 ± 15 (26-81)	67 ± 12 (32-78)	65 ± 15 (25-77)	67 ± 15 (27-82)	65 ± 14 (33-79)
Chl-a (µg.l^{-1})	0.07 ± 0,04	825 ± 817 (0.7-1702)	309 ± 312 (0.3-756)	400 ± 373 (0.4-972)	129 ± 130 (0.3-357)	157 ± 127 (0.2-300)	88 ± 71 (0.3-189)
Pheop. (µg.l^{-1})	0.10 ± 0,05	341 ± 342 (0.7-875)	208 ± 202 (0.2-556)	215 ± 173 (0.4-467)	81 ± 74 (0.1-194)	69 ± 51 (0.1-142)	44 ± 35 (0.2-93)
Chl.a / Org.matter (µg.mg^{-1})	0,02 ± 0,01	9,1 ± 8,1 (0.03-50.1)	5,1 ± 4,5 (0.09-15.0)	6,5 ± 5,0 (0.11-23.9)	3,1 ± 2,4 (0.10-14.0)	4,1 ± 2,9 (0.09-15.0)	2,4 ± 1,9 (0.09-13.2)
Particulate-N (mg.l^{-1})	0.05 ± 0,04 (0.006-0.13)	1.08 ± 0,84 (0.01-2.54)	0.48 ± 0,34 (0.04-1.00)	0.50 ± 0,29 (0.03-0.89)	0.27 ± 0,18 (0.05-0.54)	0.16 ± 0,11 (0.02-0.33)	0.14 ± 0,10 (0.03-0.27)
Dissolved							
(NH_4^+-NH_3)-N (µg.l^{-1})	66.9 ± 73.8 (7-299)	3237 ± 2215 (488-7469)	2685 ± 1308 (391-4582)	1709 ± 1237 (578-4680)	1199 ± 544 (502-2164)	710 ± 709 (175-2479)	637 ± 347 (185-1310)
(NO2-NO3)-N (µg.l^{-1})	10.4 ± 7.5 (1.7-25.4)	2577 ± 4472 (1.0-12745)	291.7 ± 510.9 (0.1-1424)	92.5 ± 159.8 (1.0-426.8)	77.0 ± 116.2 (0.7-314.4)	3.6 ± 4.7 (0.1-9.2)	0.5 ± 1.0 (0.1-2.2)
Organic-N (µg.l^{-1})	709 ± 452 (240-1949)	8099 ± 5859 (942-15139)	3496 ± 4656 (267-11316)	3027 ± 234 (706-5440)	2707 ± 2897 (585-8357)	1593 ± 1200 (439-3753)	1262 ± 803 (447-2291)
Total dissolved-N (µg.l^{-1})	735 ± 404 (335-1997)	14226 ± 9451 (971-24339)	6425 ± 4998 (1307-13130)	4424 ± 3100 (760-7944)	2689 ± 1611 (645-4885)	1974 ± 1165 (619-4117)	1770 ± 1278 (632-3603)

Similar observations could be observed for parameters related to suspended matter, such as particulate organic matter, particulate nitrogen, chlorophyll-a.For this last parameter concentrations in outflow decreases from 825 ± 817 µg.l^{-1} in pond 0 % renewal, to 88 ± 71 µg.l^{-1} in pond 40 % renewal. The high standard error affecting the mean is the consequence of the high variability of those parameters during the course of the experiment, du to a bloom of phytoplankton in the ponds. As an example of variations during the rearing cycle, **figure 14** shows the variations of the concentrations of Chl-a and of particulate N during the rearing. the highest concentrations are observed in the pond with 0 % water renewal rate. Furthermore, the highest concentrations are shown at the end of the rearing, where they can reach values up to 1800 µg.l^{-1} in this pond. The lowest concentrations are shown in ponds with the highest renewal rates, i.e. 20, 30 and 40 % d^{-1}.



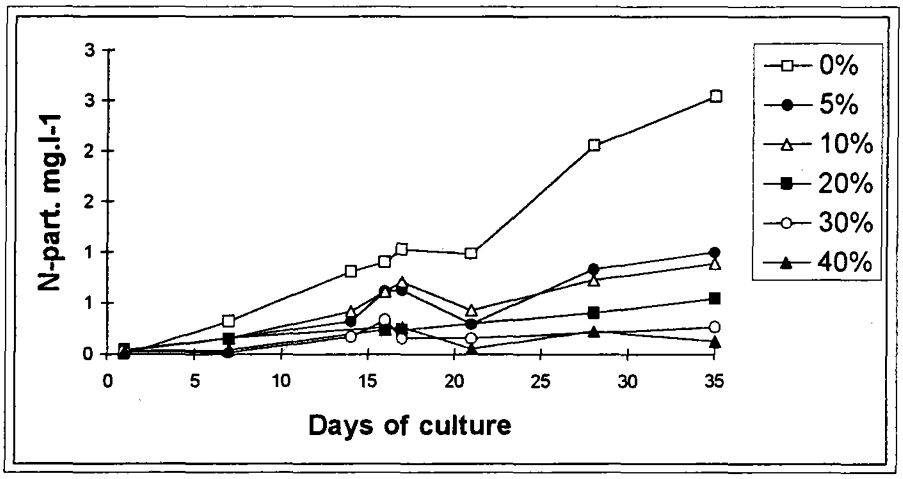
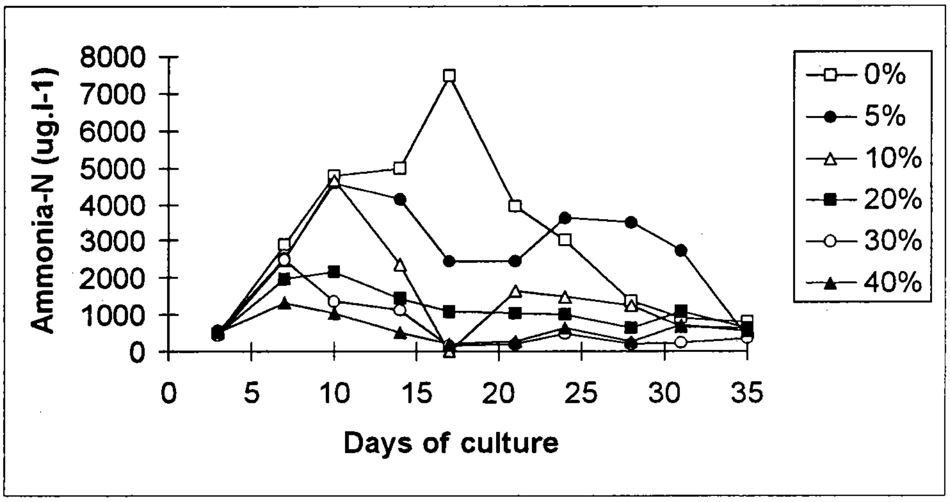


Figure 14. Variations of Chl-a and particulate N in relation to water renewal rate.

Concerning dissolved compounds, in all the ponds, huge concentrations may be observed between inflow and outflow. Furthermore, like for suspended solids, the concentrations decreased in the outflows with the increase of water renewal rate. Thus, for $(NH_3\text{-}NH_4^+)$-N, average concentration is 3237±2215 µg.l^{-1} in the 0 % exchange pond and 637±347 µg.l^{-1} in the 40 % exchange pond. For $(NO_2^-+NO_3^-)$-N, the concentrations decreases from 2577±4472 µg.l^{-1} in pond 0 % renewal, to 0.5±1.0 µg.l^{-1} in pond 40 % renewal. **Figure 15** shows the variations of $(NH_3^+\text{-}NH_4)$-N and of (NO2-+NO3-)-N in the ponds during the course of the rearing. It appears that $(NH_4^+ + NH_3)$-N concentrations are maximal at middle of rearing and minimal at rearing beginnings and ends. Concentrations of (NO_2^-+NO_3^-)-N increase at the end of culture, while concentrations of (NH_4^+-NH_3)-N decrease. This is especially obvious for pond with lower water exchange rates, i.e. 0 and 5 %.



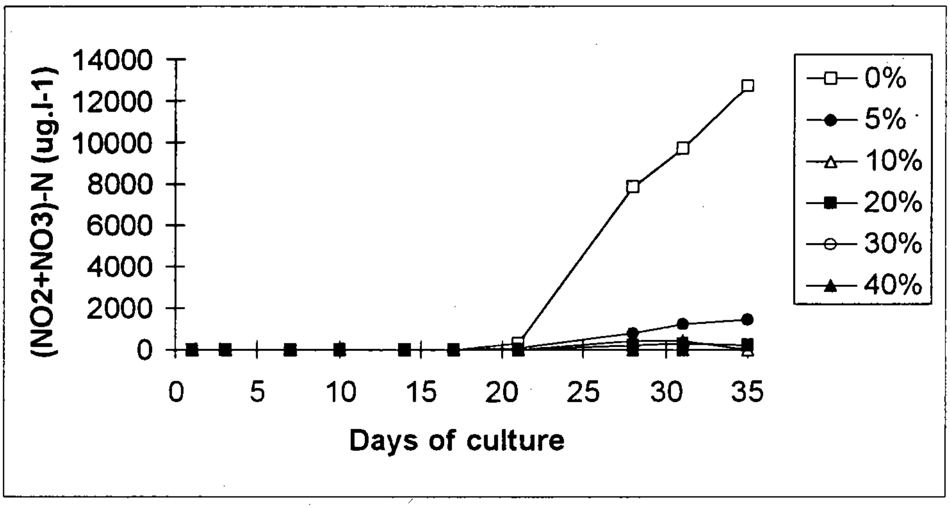


Figure 15. Variations of (NH3-NH4$^+$)-N and of (NO2^{--}-NO3^{--})-N concentrations in the ponds during the rearing experiments.

Characteristics of collected sludge are shown in **table 29**. The quantity of sludge collected at the end of the rearing decreased with increasing water renewal rate. Thus, 4740 g sludge were collected in the pond 0 % renewal rate, and 1794 g in the 40 % one. The percentage of organic matter ranges from 45 to 60 %. Total nitrogen concentration ranges from 28.6 mg.g^{-1} to 41.7 mg.g^{-1}. It is to be noticed that the lowest concentrations of organic matter and of nitrogen in sludge are observed for ponds were the renewal rate is the highest (30 and 40 %).

Table 29. Effect of water exchange rate. Sludge characteristics at the end of culture.

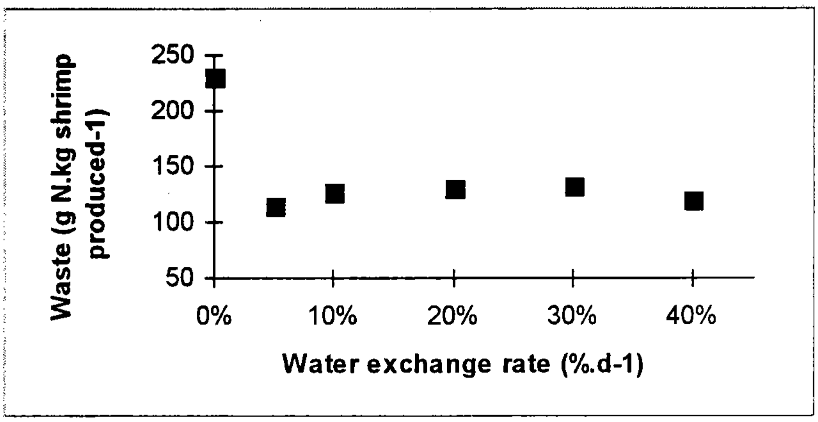
Water exchange (%.day^{-1})	0 %	5 %	10 %	20 %	30 %	40 %
collected dry weight (g)	4740	4253	2885	3157	2034	1794
organic matter (% d.w.)	60	52	56	53	50	45
total N (mg.g^{-1} d.w.)	33,5	35,3	41,7	35,4	31,2	28,6

Nitrogen budget is shown on **table 30**. The maximum of waste-N (line F), was observed in the pond 0 % renewal. In that pond, the feed efficiency-N was the lowest (line E). It represents 11.4 %, while in other ponds it ranges from 16.1 to 19.9 %. The quantity of waste-N produced per kg shrimp reared is 230 g in the 0 % renewal rate, and ranged from 114 to 131 g in the other ponds. Nitrogen input by inflowing water (line L) ranges from 0.8 to 11.0 $g.m^{-2}$, representing from 2 to 18 % of total nitrogen inputs (line N). Nitrogen output by outflowing water (line O) represents from 42 to 46 % of total input. Shrimp output (line Q) represents 11 % of total N-input (lone N) in pond 0% renewal, and from 13 to 19 % in other ponds. Sludge-N output (line P) represents from 6 to 24 % of total input-N (line N), for ponds 0 % renewal to pond 40 % renewal. The share of sludge-N (line P) collected in the pond at the end of the rearing decrease with increasing water renewal rate, from 24 to 6 % of total input-N (line N). On the contrary, the share of atmosphere-N (line R) increases with increasing water renewal rate. It may represent up to 35 % of total-N input. It is to be noticed that the total waste-N produced in the ponds (line H) shows only a slight variation what ever be the rate of renewal water. This quantity of waste varies from 40.7 to 44.3 $g.m^{-2}$ ponds. However, distribution of waste between water (line I), sludge (line J) and atmosphere (line K) is affected by the water exchange rate. (**figure 16**) shows that waste-N in water and in sludge decreases correlatively to an increase in water exchange, while waste-N in atmosphere increases.

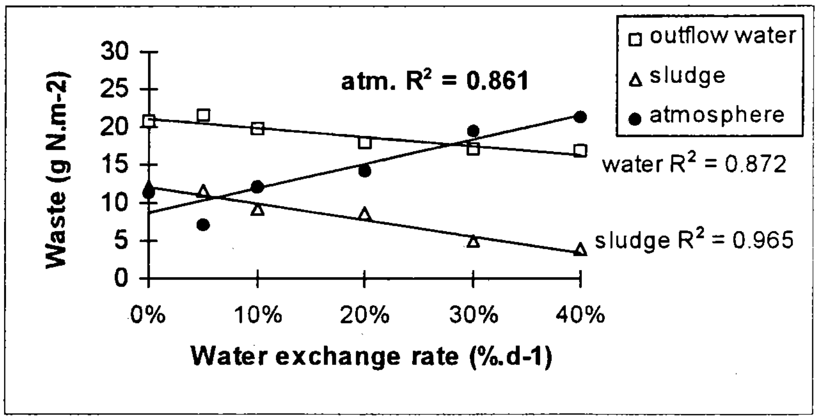
Table 30. Effects of water exchange rate on the nitrogen budgets in ponds[a].

Water exchange (%.day^{-1})	0 %	5 %	10 %	20 %	30 %	40 %
A surface of pond (m^2)	13	13	13	13	13	13
B shrimp production (g Wet Weight)	2501	4562	4228	4016	4051	4559
C total feed-N (g.pond^{-1})	650.0	652.6	652.6	655.2	657.8	652.6
D shrimp produced-N (g.pond^{-1})	74.1	130.0	118.3	126.1	118.3	105.3
E feed efficiency-N (%)	11.4	19.9	18.1	19.2	18.0	16.1
F total waste-N (g.pond^{-1})	575.9	522.6	534.3	529.1	539.5	547.3
G waste-N (g.kg^{-1} shrimp produced)	230	114	126	131	133	120
H total waste-N (g.m^{-2})	44.3	40.2	41.1	40.7	41.5	42.1
I outflow water waste-N (g.m^{-2})	20,7	21,6	19,8	17,8	17,1	16,8
J sludge waste-N (g.m^{-2})	12,2	11,5	9,3	8,6	4,9	3,9
K atmosphere waste- N (g.m^{-2})	11,3	7,0	12,0	14,2	19,5	21,3
Input-N (g.m^{-2})						
L water-N (dissolved + particulate)[b]	0,8 (2)	2,0 (4)	3,4 (6)	5,9 (10)	8,4 (14)	11,0 (18)
M feed pellets-N[b]	50,0 (98)	50,2 (96)	50,2 (94)	50,4 (90)	50,6 (86)	50,2 (82)
N total input-N	50,8	52,2	53,6	56,3	59,0	61,2
Output-N (g.m^{-2})						
O water-N (dissolved + particulate)[b]	21,5 (42)	23,7 (45)	23,2 (43)	23,7 (42)	25,5 (43)	27,9 (46)
P sludge-N[b]	12,2 (24)	11,5 (22)	9,3 (17)	8,6 (15)	4,9 (8)	3,9 (6)
Q shrimp-N[b]	5,7 (11)	10,0 (19)	9,1 (17)	9,7 (17)	9,1 (15)	8,1 (13)
R atmosphere-N[b]	11,3 (22)	7,0 (13)	12,0 (22)	14,2 (25)	19,5 (33)	21,3 (35)

[a] The different compartments of nitrogen were calculated with the same method as in the previous experiment.
[b] Numbers between brackets are percents of total input-N.



(a)



(b)

Figure 16. Production (a) and fate (b) of waste-N in ponds, in relation to water exchange rate.

Table 31 shows the fate of feed-N in the different compartments. It appears that, except for pond 0% renewal, the share of feed-N accumulated in shrimp is similar, from 16.1 to 19.9 %, whatever the renewal rate. In the mean time, the share in outflow decreases (from 43.2 to 33.7 %) as well as the share in sludge (22.9 to 7.8 %). The share of feed-N corresponding to diffusion and/or denitrification increases with increasing water renewal rate, from 13.9 to 42.5 % for ponds 5 and 40 % renewal rate respectively.

Table 31. Fate of Feed-N in rearing ponds: influence of water renewal rate for intensive conditions.

Water renewal (% day)	Stocking density (PL/m^2)	% in shrimp	% in outflow	% in sediment	% to atmosp.
0	86 (323)*	11.4	41.4	24.4	22.6
5	86 (323)*	19.9	43.2	22.9	13.9
10	86 (323)*	18.1	39.4	18.5	23.9
20	86 (323)*	19.2	35.3	17.1	28.2
30	86 (323)*	18	33.8	9.7	38.5
40	86 (323)*	16.1	33.7	7.8	42.4

* between bracket is shown the initial biomass in the pond, expressed as g.m^{-2} pond.

1.2.3.2.2.3. Discussion

The reduction of water exchange rates from 40 % to 0 % shows a consequence on the survival rate only in the case of 0 % water exchange. Moreover in that pond, shrimp growth is lower than in the other ponds. For the 0 % water exchange pond the amount of waste produced per kilogram of shrimp produced is on top of the waste amounts produced in the other ponds. For the other ponds shrimp growth, shrimp mortality and waste production are similar whatever the water exchange rate. The mortality increase and the growth decline in the 0 % exchange pond could be explained by high concentrations of $(NH_4^+ + NH_3)$-N reaching actually values beyond 7000 $\mu g.l^{-1}$. In the case of the other ponds, nutrient compounds in water although lower than in 0 % exchange can also show high concentrations. Concentrations of $(NH_4^+ + NH_3)$-N range between 391 and 4680 $\mu g.l^{-1}$ in 5 and 10 % exchange ponds. These concentrations do not appear toxic for shrimp. Besides measured values of pH and oxygen are in all cases within the range of values which are considered non toxic for Penaeids (Seidman *et al.*, 1985 ; Allen *et al.*, 1991 ; Fast *et al.*, 1992 ; Lawrence, 1995). It has for consequence to limit the effect of $(NH_4^+ + NH_3)$-N (Allan *et al.*, 1990).

When water exchange rate increases there is a decrease of the waste proportion in outflow and in sludge, meanwhile this proportion increases in the part discharged to the atmosphere. This observation is in opposition with those made for earthen ponds (see **chapters 1-2-3-2-1**) in which nitrogen loss to the atmosphere increased with the reduction of water exchange rates. It should be noticed that in the case of concrete intensive ponds sludge deposition on pond bottom decreases when water exchange rate increases. Furthermore in concrete ponds, the lowest concentrations of organic matter and of nitrogen in sludge are observed in ponds were the renewal rate is the highest (30 and 40 %). Mineralisation of organic sludge could be faster in concrete ponds than in earthen ponds. No explanation can be given to that difference in the future of waste between concrete and earthen ponds. It could appear that the capacity to accumulate waste within the sediment then to mineralise them could be the reason for these differences. That difference in mineralisation between concrete and earthen ponds can be related in the case of our study to the effect of temperature. Actually the study of influence of water exchange rate in extensive to semi intensive system (earthen ponds) has been carried out in winter season in New Caledonia when morning temperatures ranged from 19 to 26.9° C. During the study of the same parameters in intensive system (concrete ponds) conducted in Tahiti morning temperatures ranged from 25.0 to 29.4° C. The bacterial activity of mineralisation which increases with temperature (Manguiat *et al.*, 1996 ; Gouleau *et al.*, 1996; Holmer and Kristensen, 1994 ; Zimmerman and Benner ; Rajendran and Venugopalan, 1977), could explain differences of deposition and loss to the atmosphere observed between the two systems.

1.2.4. Synthesis and conclusions

In terms of waste produced by shrimp aquaculture, two types of culture must be considered: cultures carried out in earthen ponds and cultures carried out in concrete ponds. The last type can inform us of what is occurring in cultures carried out on liners, i.e. both are conducted without the influence of sediment and of geochemical process which take place inside it. Intensification is additionally accompanied very often by an oxygen supply (through paddle wheel, airlift or injection aerators). Furthermore, the comparison of different experiments realised on a same location and in the same ponds show explanation problems. When comparing, for instance, the fate of feed-N in concrete intensive ponds, it can be seen that the proportions of sludge deposited-N vary between experiments. They are, in one case, lower than 3.2 % (**table 19**) and, in the other case, ranging from 7.8 to 24.4 % (**table 31**). Meanwhile waste-N discharged through outflow ranged from 59.7 to 78.6 % in the first case

(table 19) and represented less than 43.2 % in the second one **(table 31)**. This can be caused by the difference of temperature occurring during the two experiments. As matter of fact in the first one the mean evening temperature ranged between 30.3 and 30.7° C **(table 15)**, while in the second one it ranged from 28.2 to 28.6° C **(table 27)**. This difference allows to consider the microbial degradation of organic matter increases in ponds with higher temperatures, with as consequences an increasing primary production rate. If we actually compare what can be compared, in terms of water exchange rates on one hand and in terms of stocking biomass on the other hand, we can notice in concrete ponds that chlorophyll concentrations are higher in the pond with 75 shrimp.m^{-2} **(table 16)** than in the pond with 20 % water exchange **(table 28)**. Mean chl-a concentrations measured are respectively 241 and 129 ug.l^{-1}. Stocked biomass are very close in both ponds and water exchange rates are equal (20 %). That is why the fate of waste stemming from feed pellets through nutrition/excretion process will be depending on various elements so as (i) the existence or not of sediment, (ii) the rearing density, (iii) the water exchange rate as well as (iv) factors like temperature. As a consequence, more variables are introduced in the analysis of the considered budgets. For all those reasons and because several variables interfere, the comparison of various types of experiments carried out in earth and in concrete ponds at different seasons can be only done very carefully.

Table 32 gives data regarding the nitrogen fate related to feed pellets. This synthetic table shows waste amounts produced by shrimp culture under different zootechnical conditions tested. The more noticeable elements regarding the amounts of waste produced and their fate are as follows:

1- In relation to the intensification

- Under semi intensive non aerated earthen ponds conditions(1-30 shrimp.m^{-2}) and in intensive aerated concrete ponds conditions (50-125 shrimp.m^{-2}) the increase of rearing densities induces an increase of waste amount per kilogram of shrimp produced, from 60.8 to 157.3 g N.kg^{-1} shrimp produced in the first case, and from 92.8 to 123.8 g N.kg^{-1} shrimp produced in the second case.
- Under semi intensive non aerated earthen ponds conditions, when the stocking density increases, the proportion of waste-N in sediment increases (from 0 to 43 % of feed-N given to shrimp), while the proportion of waste-N in outflow decreases (33.7 to 16.2 % of feed-N given to shrimp).

Table 32. Fate of Feed-N in rearing ponds: influence of stocking density and of water renewal rate.

	Stocking density (biomass.m^{-2})	Water renewal (%.d^{-1})	Feed-N (g) /kg shrimp produced	waste-N (g) /kg shrimp produced	% feed-N in shrimp	% feed-N in outflow	% feed-N in sediment (or sludge)	% feed-N to atmosp.
Earthen ponds without aeration	1 (0-29)[a]	10	93.0	60.8	34.6	-[b]	< 0[b]	-[b]
	4 (0-94)	10	107.4	75.5	29.7	33.7	22.8	13.9
	7 (0-169)	10	122.7	90.7	26.1	20.3	24.2	29.5
	15 (0-237)	10	109.5	77.5	29.2	14.2	18.8	38.1
	22 (0-196)	10	163.0	130.9	19.7	16.0	35.4	28.8
	30 (0-190)	10	189.5	157.3	17.0	16.2	43.0	23.8
concrete ponds with airlifts	50 (197-430)	20	120.1	92.8	22.7	59.7	3.2	14.4
	75 (295-624)	20	124.4	97.4	21.7	66.3	2.4	9.5
	100 (394-780)	20	137.0	109.9	19.8	64.5	2.1	13.4
	125 (492-897)	20	151.0	123.8	18.0	78.6	2.0	1.5
Earthen ponds without aeration	20 (0-133)	10	183.3	151.0	17.6	16.4	32.4	33.6
	20 (0-157)	11	163.5	131.0	19.9	14.8	22.3	43.0
	20 (0-137)	17	185.2	153.2	17.3	15.7	21.7	45.3
	20 (0-180)	17	150.0	117.9	21.4	14.5	19.6	44.6
	20 (0-184)	21	159.6	127.5	20.1	10.1	47.6	21.9
	20 (0-193)	23	153.4	121.3	20.9	16.8	37.7	24.6
Concrete ponds with airlifts	86 (323-515)	0	259.9	230.3	11.4	41.4	24.4	22.6
	86 (323-669)	5	143.1	114.6	19.9	43.2	22.9	13.9
	86 (323-646)	10	154.4	126.4	18.1	39.4	18.5	23.9
	86 (323-631)	20	163.1	131.8	19.2	35.3	17.1	28.2
	86 (323-631)	30	162.4	133.2	18.0	33.8	9.7	38.5
	86 (323-669)	40	143.1	120.1	16.1	33.7	7.8	42.4

[a] between bracket is shown the initial and final biomass in the pond, expressed as g.m^{-2} pond.
[b] Calculation of sharing of N-waste was not possible du to the fact that, in that case, sediment was a source of nitrogen, rather than an accumulator (see relevant chapter).
Dark cells indicate the variable in the experiments.

- Under intensive aerated rearing in concrete ponds conditions, the amounts of deposited waste on pond bottom are always small (2.0 to 3.2 % of feed-N given to shrimp), and do not depend on the rearing density, in the limits of the stocking biomass experimented. In such conditions, waste are mostly discharged with outflow water (up to 78.6 % of feed-N given to shrimp).

2- In relation to the water exchange rate

- Under semi intensive non aerated earthen ponds conditions, the increase of water exchange rate (10 to 23 %.pond^{-1}) induces the reduction of waste amount per kilogram of shrimp produced (153.2 to 121.3 N.kg^{-1} shrimp produced). In the mean time, the proportion of waste-N accumulating in the sediment increases (up to 47.6 % of feed-N given to shrimp).
- Under intensive aerated rearing in concrete ponds conditions, the increase of water exchange rate above 5 %.d^{-1} does not improve the performance of feed-N assimilation and, so, the quantity of waste-N produced (between 114.6 and 133.8 g waste-N.kg^{-1} shrimp produced for water renewal rate ranging from 5 to 40 % d^{-1}). In the mean time, the increase of water renewal rate leads to a decrease in the proportion of sludge accumulating on pond bottom (24.4 to 7.8 % of feed-N given to shrimp).

The different types of management can lead to variable quantities of wastes for a same quantity of shrimp produced. Furthermore, the sharing and fate of the waste produced differs also, from on type of management to the other. Our study was conduced, taking into account what can be considered as the limits of the systems (from 1 to 125 shrimp.m^{-2}). From our results, it is possible to compare, from one experiment to the other, the quantities of wastes generated for similar management parameters, more representative of the kind of management which are generally operated. Thus, for semi intensive rearing, 4 ponds can be compared, which present similar parameters (15 to 22 shrimp.m^{-2}, and 10 and 11 % water renewal rate). **Table 33** shows for such representative conditions the data, and the means of discharge, sharing and fate of wastes. So, the average production of wastes in semi extensive conditions (15 to 22 shrimp.m-2), with water renewal rate is 122.6 g waste-N per kg shrimp produced. In such conditions, the sharing of N-feed pellets is the following one: 21.6 % in shrimp, 15.4 % is discharged outside the pond with outflow, 27.2 % accumulate in the sediment, and 35.9 % let out to the atmosphere.

Table 33. Fate of Feed-N in rearing ponds showing similar management characteristics, for semi-intensive rearing in earthen ponds on the one hand, and intensive rearing conditions in concrete ponds on the other hand. Between brackets are shown rearing biomass at the beginning and at the end of the experiment.

	Stocking density (biomass.m^{-2})	Water renewal (%.d^{-1})	waste-N (g) /kg shrimp produced	% feed-N in shrimp	% feed-N in outflow	% feed-N in sediment (or sludge)	% feed-N to atmosp.
Earthen Ponds	15 (0-237)	10	77.5	29.2	14.2	18.8	38.1
	22 (0-196)	10	130.9	19.7	16.0	35.4	28.8
	20 (0-133)	10	151.0	17.6	16.4	32.4	33.6
	20 (0-157)	11	131.0	19.9	14.8	22.3	43.0
Mean			122.6	21.6	15.4	27.2	35.9
concrete ponds	75 (295-624)	20	97.4	21.7	66.3	2.4	9.5
	86 (323-631)	20	131.8	19.2	35.3	17.1	28.2
Mean			114.6	20.5	50.8	9.8	17.9

For intensive rearing conditions in concrete ponds (stocking density, 75-86 shrimp.m-2, water renewal rate 20 %), 114.6 g N-waste are generated per kg shrimp produced. The average proportion of feed-N in the different compartments are the following one: 20.5 % in shrimp, 50.8 % in outflow, 9.8 % in sludge, 17.9 % to atmosphere.

The experimental approach we have made, allowed to determine, in « field » conditions, the quantities of wastes, their sharing and their fate, for several management conditions. It is to be noticed that these experiments have been carried out with *Penaeus stilyrostris*, which is the species commonly grown in pacific islands were the rearing were performed. It would be advisable to confirm in the future those data for the most common species grown in the word, that is to say *P. monodon*. Nevertheless, du to the similitude of physiology and behaviour of *P. stylirostris* and *P. monodon*, one can assess that the data got for on species can be suitable for the other. Those data would allow to anticipate the quantities and the nature of wastes, in relation to the expected biomass of shrimp production, for any given potential site, and so, to bring essential information on the anticipation of a potential impact (cause-effect relationship), and on the carrying capacity and sustainability of the site.

1.2.5. References

Ackefors H., Enell M., 1990. Discharge of nutrients from Swedish fish farming to adjacent sea areas. *Ambio*, 19: 28-35.

Allan G.L. and Maguire G.B., 1991. Lethal effects of low dissolved oxygen and effects of short-term oxygen stress on subsequent growth of juvenile *Penaeus monodon*. Aquaculture, 94: 27-37.

Allan G.L. and Maguire G.B., 1992. Effects of stocking density on production of *Penaeus monodon* Fabricius in model farming ponds. Aquaculture, 107: 49-66.

Allan G.L., Maguire G.B., 1993. The effect of water exchange on production of *Metapenaeus macleayi* and water quality in experimental pools. *Journal of the World Aquaculture Society*, 24(3): 321-328.

Allan G.L., Maguire G.B. and Hopkins S.J., 1990. Acute and chronic toxicity of ammonia to juvenile *Metapenaeus macleayi* and *Penaeus monodon* and the influence of low dissolved oxygen levels. Aquaculture, 91: 265-280.

Allan G.L., Moriarty D.J.W. and Maguire G.B., 1995. Effects of pond preparation and feeding rate on production of *Penaeus monodon* Fabricius, water quality, bacteria and benthos in model farming ponds. Aquaculture, 130: 329-349.

Aquacop, 1984. Review of ten years of experimental penaeid shrimp culture in Tahiti and New Caledonia (South Pacific). *Journal of the World Mariculture Society*, 15: 73-91.

Armstrong F.A.J. and Tibbits S., 1968. Photochemical combustion of organic matter in sea-water, for nitrogen, phosphorus and carbon determination. J. Mar. Biol. Ass. U.K., 48: 143-152.

Avnimelech Y., Lacher M., Raveh A., Zur O., 1981. A method for the evaluation of conditions in a fish pond sediment. *Aquaculture*, 23: 361-365.

Avnimelech Y., Mozes N. and Weber B., 1992. Effects of aeration and mixing on nitrogen and organic matter transformations in simulated fish ponds. *Aquacultural Engineering*, 11: 157-169.

Ayud M., Boyd C.E., 1994. Comparison of different methods for measuring organic carbon concentrations in pond bottom soils. *Journal of the World Aquaculture Society*, 25(2): 322-325.

Baticados M.C.L., Coloso R.M., Duremdez R.C., 1986. Studies on the chronic soft-shell syndrome in the tiger prawn *Penaeus monodon* Fabricius from brackishwater ponds. *Aquaculture*, 56: 271-285.

Benschneider K. and Robinson R.J., 1952. A new spectrophotometric method for the determination of nitrite in seawater. J. Mar. Res., 11: 87-86.

Berthe F.C.J., Legroumellec M., Haffner P., Renault T., 1995. Histological abnormalies related to experimentally induced mortality in penaeid shrimp (*Penaeus stylirostris*) reared in New-Caledonia. Seventh Intenational Conference « Diseases of fish and shellfish ». European Association of Fish Pathologists. Palma de Mallorca, 10-15 septembre 1995. Abstract.

Blackburn T.H., Lund B.A., Krom M.D., 1988. C- and N-mineralization in the sediments of earthen marine fishponds. *Marine Ecology Progress Series*, 44: 221-227.

Boyd C.E., 1990. Water quality in ponds for Aquaculture. Alabama Agricultural Experiment Station. Auburn University, Alabama, 482 p.

Boyd C.E., 1992. Shrimp pond bottom soil and sediment management. In J. Wyban (Editor), Proceedings of Special Session on Shrimp farming, Aquaculture 92, World Aquaculture Society, Baton Rouge, Louisiana, USA, pp. 166-181.

Boyd C.E., Tanner, M.E., Madkour, M. and Masuda, K., 1994. Chemical characteristics of bottom soils from freshwater and brackishwater aquaculture ponds. J. World Aquacult. Soc., 25 (4): 517-534.

Browdy C.L., Holloway J.D., King C.O., Stokes A.D., Hopkins J.S., Sandifer P.A., 1993. IHHN virus and intensive culture of *Penaeus vannamei*: Effects of stocking density and water exchange rates. *Journal of Crustacean Biology* 13(1): 87-94.

Blackburn T.H., Lund B.A. and Krom M.D., 1988. C- and N- mineralization in the sediments of earthen marine fishponds. Mar. Ecol. Prog. Ser., 44: 221-227.

Briggs M.R.P., 1993. Water quality in sustainable shrimp farming. In: The Third Academic and Research Conference for Southern Thailand Technical Colleges. Krabi, Thailand 23-25 July, 1993, 46 pp.

Briggs M.R.P. and Funge-Smith, S.J., 1994. A nutrient budget of some intensive marine shrimp ponds in Thailand. Aquacult. Fish. Manage., 25: 789-811.

Burford M., 1997. Phytoplankton dynamics in shrimp ponds. *Aquaculture Research*, 28:351-360.

Cam D., Rollet P.E., Mariotti A., Guillaume J. 1991. Contribution relative de la productivité naturelle et de l'aliment composé dans la nutrition de *Penaeus japonicus* élevé en conditions semi-intensives. *Aquat. Living Resour.*, 4: 175-180.

Chamberlain G.W., 1987. Intensification reasonable from economic point of view. *Coastal Aquaculture* 4(1): 1-7.

Chamberlain G.W., 1988. Rethinking shrimp pond management. *Coastal Aquaculture*, 5(2): 1-20.

Chen I.M., Huang J.C. and Lee S., 1990a. The effects of a paddlewheel on the nutrient dynamics in a shrimp pond. In: R. Hirano, and I. Hanyu (Editors), Proceedings the Second Asian Fisheries Forum, Tokyo, Japan, 17-22 April 1989. pp. 125-128.

Chen J.C., Ting Y.Y., Lin J.N. and Lin M.N., 1990b. Lethal effects of ammonia and nitrite on *Penaeus chinensis* juveniles. Mar. Biol., 107: 427-431.

Chen J.C. and Lei S.C., 1990. Toxicity of ammonia and nitrite to *Penaeus monodon* juveniles. J. World Aquacult. Soc., 21 (4): 300-306.

Chien Y.H., 1989. Study on the sediment chemistry of tiger prawn, Kuruma prawn, and red tail prawn ponds in I-Lan Hsien. COA. Fish. Ser., 16: 257-275.

Chien Y.H., 1992. Water quality requirements and management for marine shrimp culture. *In: Proceedings of the Special Session on Shrimp Farming* (ed. J. Wyban) World Aquaculture Society, Baton Rouge, LA, pp. 144-156.

Chua T.E., 1992. Coastal aquaculture development and the environment. *Marine Pollution Bulletin*, 25: 98-103.

Chua T.E., 1993. Environmental management of coastal aquaculture development. In: Environment and Aquaculture in Developing Countries. In: R.S.V. Pullin, H. Rosenthal and J.L. Maclean (Editors). ICLARM Conf. Proc., 31: 199-212.

Clifford H.C., 1985. Semi-intensive shrimp farming. *In G.W. Chamberlain editor. Texas shrimp farming manual.* Texas Agriculture Extension Service, Texas Shrimp Farming Workshop, 19-20 november 1985, Corpus Christi, Texas, USA.

Clifford H.C., 1992. Marine shrimp pond management: a review. *In: Proceedings of the Special Session on Shrimp Farming* (ed. J. Wyban) World Aquaculture Society, Baton Rouge, LA, pp. 110-137.

Colt J.E., Armonstrong D.A., 1981. Nitrogen toxicity to crustaceans, fish and molluscs. Pages 34-47 in L.J. Allen and E.C. Kinney, editors. *Proceedings of the bio-engineering symposium for fish culture.* Fish culture section of the American Fisheries Society, Bethesda, Maryland, USA.

Costa R., Mermoud I., Koblavi S., Haffner P., Berthe F., Le Groumellec M., Grimont P., 1996a. Isolation and characterisation of bacteria associated with a *Penaeus stylirostris* (« syndrome 93) in New Caledonia. *Second International Conference on the culture of penaeid prawns and shrimp.* Iloilo, Philippines 17-17 may 1996. Seafdec, publisher. Abstract, pp 44.

Costa R., Mermoud I., Morlet B., Haffner P., Koblavi S., Grimont P., 1996b. Study of episodes of mortality observed in reared *Penaeus stylirostris* since 1993 in New Caledonia: II - Isolation ans identification of bacteria collected from the hemolymph of moribund prawns during peaks of mortality. *The 1996 Annual Meeting of The World Aquaculture Society*. Bangkok, Thailand, January 29 - February 2, 1996. Book of abstract, pp 91.

Daniels H.V., Boyd C.E., 1989. Chemical budgets for polyethylene-lined, brackiswater ponds. *Journal of the World Aquaculture Society* 20(2): 53-60.

Daniels W.H., D'Abramo L.R., Fondren M.W. and Durant M.D., 1995. Effects of stocking density and feed on pond production characteristics and revenue of harvested freshwater prawns *Macrobrachium rosenbergii* stocked as size-graded juveniles. J. World Aquacult. Soc., 26 (1): 38-47.

Egusa S., 1961. Studies on the respiration of the « Kuruma » prawn *Penaeus japonicus* bates. II. Preliminary experiments on its oxygen consumption. *Bull. Japanese Soc. Sci. Fish.* 27: 650-659.

FAO, 1992. Aquaculture production 1984-1990. Fisheries Circular, 185 Rev. 4, Rome, 206 pp.

Fast A.W. and Boyd C.E., 1992. Water circulation, aeration and other management practices. In: A.W. Fast, and L.J. Lester (Editors), Marine shrimp culture: principles and practices. Elsevier Scientific Publishers, Amsterdam, pp. 457-495.

Flegel T.W., Fegan D.F., Sriurairatana S., 1995. Environmental control of infectious shrimp diseases in Thailand. In: *diseases in Asian Aquaculture II*. M. Shariff, J.R. Arthur and R.P. Subasinghe (eds.), p. 65-79. Fish health section, Asian Fisheries Society, Manila.

Folke C. and Kautsky N., 1992. Aquaculture with its environment: prospects for sustainability. Ocean Coast. Manage., 17: 5-24.

Funge-Smith S.J., 1993. The nature of sediment in intensive shrimp ponds. In: The Third Academic and Research Conference for Southern Thailand Technical Colleges. Krabi, Thailand 23-25 july, 1993, 7 pp.

Funge-Smith S.J. and Briggs M., 1996. Intensive shrimp pond nutrient budgets. Implication for sustainability. Second International Conference on the Culture of Penaeid Prawns and Shrimp. Iloilo, Philippines 14-17 may 1996. Seafdec, publisher. Abstract, pp. 21.

Garnier J. and Barillier A., 1991. Synthèse et dégradation de la matière organique dans les écosystèmes aquatiques: boucle microbienne et statut trophique. Océanis, 17 (5): 561-580.

Ghost S.R. and Mahanty A.N., 1981. Observations on the effect of aeration on mineralization of organic nitrogen in fish pond soil. *Bamidgeh,* 33(2): 51-55.

Goarant C., Mermoud I., Costa R., Haffner P., Boglio E., 1996. Study of episodes of mortality observed in reared *Penaeus stylirostris* since 1993 in New Caledonia: I - Biotechnical impact and goss signs in diseased prawns. *The 1996 Annual Meeting of The World Aquaculture Society*. Bangkok, Thailand, January 29 - February 2, 1996. Book of abstract, pp 139.

Goxe D., 1988. Influence of daily water change on medium quality and growth of *Penaeus stylirostris* in semi-intensive culture conditions in New Caledonia. *Journal of the World Aquaculture Society* (Aquaculture communiques) 19(1): 32A-33A.

Gouleau D., Feuillet-Girard M., Germaneau J. and Robert S., 1996. Effets de l'assèchement des bassins ostréicoles sur le cycle biogéochimique de nutriments azotés: ammonification préférentielle. Oceanol. Acta, 19 (2): 101-115.

Hosumi M., Sudo R., 1986. Simultaneous determination of total nitrogen and total phosphorus in freshwater sample using persulfate digestion. *Int. J. Environ. Stud.* 27: 267-275.

Hussenot J., Martin J.L.M., 1995. Assessment of the quality of pond sediment in aquaculture using simple, rapid techniques. *Aquaculture International*, 3: 123-133.

Hedges J.I. and Stern J.H., 1984. Carbon and nitrogen determinations of carbonate-containing solids. Limnol. Oceanogr., 29: 657-663.

Herbland A., 1975. Utilisation par la flore hétérotrophe de la matière organique naturelle dans l'eau de mer. *J. Exp. Mar. Biol. Ecol.*, 19: 19-31.

Hirayama K., Mizuma H., Mizue., 1988. The accumulation of dissolved organic substances in close recirculation culture systems. *Aquacultural Engineering*, 7: 73-87.

Hirono Y., 1992. Current practices of water quality management in shrimp farming and their limitations. In: *Proceedings of the Special Session on Shrimp Farming* (ed. J. Wyban) World Aquaculture Society, Baton Rouge, LA, pp. 157-165.

Holm-Hansen O., Lorenzen C.J., Holmes P.E., Strickland J.D.H., 1965. Fluorometric determination of chlorophyll. *Journal du conseil internationale pour l'exploitation de la mer*, 30: 3-15.

Holm-Hansen O. and Riemann B., 1978. Chlorophyll-a determination: improvements in methodology. Oikos, 30: 438-447.

Holmer M.; Kristensen E., 1994. Organic matter mineralization in an organic-rich sediment: Experimental stimulation of sulfate reduction by fish food pellets. Fems Microbiol. Ecol., 14, 1, 33-44.

Hopkins J.S., Hamilton II R.D., Sandifer P.A., Stokes A.D., Browdy C.L., 1991. Effects of minimal water exchange on the water quality and production of intensive marine shrimp ponds. *Program and abstracts, 22nd Annual Conference and Exposition*, World Aquaculture Society, June 1991, San Juan, Puerto Rico.

Hopkins J.S., Hamilton R.D., Sandifer P.A., Browdy C.L. and Stokes A.D., 1993. Effect of water exchange rate on production, water quality, effluent characteristics and nitrogen budgets of intensive shrimp ponds. J. World Aquacult. Soc., 24 (3): 304-320.

Hopkins J.S., Sandifer P.A. and Browdy C.L., 1994. Sludge management in intensive pond culture of shrimp: effect of management regime water quality, sludge characteristics, nitrogen extinction, and shrimp production. Aquacult. Eng., 13: 11-30.

Hopkins J.S., Sandifer P.A. and Browdy C.L., 1995. A review of water management regimes which abate the environmental impact of shrimp farming. In: C.L. Browdy and J.S. Hopkins (Editors), Swimming through troubled water. Proceedings of the Special Session on Shrimp Farming, Aquaculture 95, World Aquaculture Society, Baton Rouge, Louisiana, USA. pp. 157-166.

Hopkins J.S., Villalón J., 1992. Synopsis of industrial panel input on shrimp pond management. *In: Proceedings of the Special Session on Shrimp Farming* (ed. J. Wyban) World Aquaculture Society, Baton Rouge, LA, pp.138-143.

Hunter B., Pruder G. and Wyban J., 1987. Biochemical composition of pond biota, shrimp ingesta, and relative growth of *Penaeus vannamei* in earthen ponds. J. World Aquacult. Soc., 18 (3): 162-174.

Kaplan W.A., Valiela I. and Teal J.M., 1979. Denitrification in salt marsh ecosystems. Limnol. Oceanogr., 24: 726-734.

Knowles R., 1982. Denitrification. *Microbiol. Rev.* 35: 43-70.

Kongheo H., 1990. Pond management and operation. Pages 56-65 *in* M.B. New, H. de Saram and T. Singh, editors. Technical and economic aspects of shrimp farming: *proceeding of the Aquatec'90 Conference*. INFOFISH, Kuala Lumpur, Malaysia.

Koroleff F., 1983. Determination of ammonia. In: K. Grasshof, M. Ehrhardt and K. Kremling (Editors), Methods of Seawater Analysis, Verlag Chemie, Weineim, RFA, pp. 150-157.

Lee, C.S., Sweeney J.N. and Richards W.K. Jr, 1986. Marine shrimp aquaculture: a novel waste treatment system. Aquacult. Eng., 5: 147-160.

Le Groumellec M., Goarant C., Haffner P., Berthe F., Costa R., Mermoud, I., 1996a. « Syndrome 93 in New Caledonia »: Investigation of the bacterial hypothesis by experimental infections, with reference to stress-induced mortality. *Second International Conference on the culture of penaeid prawns and shrimp*. Iloilo, Philippines 17-17 may 1996. Seafdec, publisher. Abstract, pp 46.

Le Groumellec M., Goarant C., Haffner P., Mermoud I., Costa R., 1996b. Study of episodes of mortality observed in reared *Penaeus stylirostris* since 1993 in New Caledonia: IV - Investigation of the bacterial hypothesis by experimental infectious, with reference to stress-induced mortality. *The 1996 Annual Meeting of The World Aquaculture Society*. Bangkok, Thailand, January 29 - February 2, 1996. Book of abstract, pp 144.

Le Groumellec M., Goarant C., Haffner P., and Aquacop, 1996c. « Syndrome 93 » in New-Caledonia: Investigation the bacterial hypothesis. *The 1996 Annual Meeting of The World Aquaculture Society.* Bangkok, Thailand, January 29 - February 2, 1996. Book of abstract, pp 145.

Lemonnier H., Martin J.L.M., 1996. Modelling the nature and quality of wastes in semi-intensive shrimp pond effluents: preliminary results. *Second International Conference on the culture of penaeid prawns and shrimp.* Iloilo, Philippines 17-17 may 1996. Seafdec, publisher. Abstract, pp 104.

Liao I.C., 1990. Aquaculture in Taiwan. In: M.M. Joseph (Editor), Aquaculture in Asia, Asian Fisheries Society, Indian Branch, Mangalore, pp. 354-369.

Lin C.K., 1989. Prawn culture in Thailand. What went wrong? World Aquacult. 20 (2): 19-20.

Maguire G.B., Leedow M.I., 1983. A study of the optimum stocking density and feeding rates for school prawns *Metapenaeus macleayi* (Haswell) in some Austalian brackish water farming ponds. *Aquaculture*, 30: 285-297.

Manguiat I.J.; Watanabe I.; Mascarina G.B.; Tallada J.G., 1996. Nitrogen mineralization in tropical wetland rice soils: 1. Relationship with temperature and soil properties Soil Sci. Plant Nutr., 42 (2), 229-238.

Martin J.-L.M., Marchand M., Shafiqul Alam A.M., 1993. Assessment of impact and effects of chemical contaminants in aquatic environments. In: M. Tilzer and M. Khondker, (Editors), Proceedings of the International Symposium on Limnology, Hypertrophic and Polluted Tropical Freshwater Ecosystems, Ecological Bases for Water Resources Management, 25-28 November 1991, University of Dakha, Bangladesh, pp. 19-37.

Martin J.L.M., Veran Y., Guelorget O., Pham D., 1997. Shrimp rearing: stocking density, growth, impact on sediment, waste output; their relationships studied through the nitrogen budget in rearing ponds. *Aquaculture*: in press.

Martinez-Cordova L.R., Villareal C. H., Porchas C.M.A., 1995. Culture of white shrimp *Penaeus vannamei* in reduced water exchange ponds in Sonora, Mexico. *Journal of the World aquaculture*, 26(4): 47-48.

Mermoud I., Costa R., Goarant C., Haffner P., 1996a. Mortalities observed in cultured Penaeus stylirostris in New Caledonia. Second International Conference on the culture of penaeid prawns and shrimp. Iloilo, Philippines 17-17 may 1996. Seafdec, publisher. Abstract, pp 45.

Mermoud I., Costa R., Lightner D., Haffner P., 1996b. Study of episodes of mortality observed in reared *Penaeus stylirostris* since 1993 in New Caledonia: III - Histological abnormalities observed in moribund prawns collected during episodes of mortality. *The 1996 Annual Meeting of The World Aquaculture Society.* Bangkok, Thailand, January 29 - February 2, 1996. Book of abstract, pp 255.

Morales J., Rodriguez J.M., Gertrudix L.J. and Berrocal D., 1991. Evolution of some chemical characteristics in soil from commercial shrimp ponds. II. Nutrients. Spec. Publ. Eur. Aquacult. Soc., 14: 223-224.

Nishio T., Koike I. and Hattori A., 1983. Estimates of denitrification and nitrification in coastal and estuarine sediments. Appl. Environ. Microbiol., 45: 444-450.

Payne W.J., 1973. Reduction of nitrogenous oxides by microorganisms. Bacteriol. Rev., 37: 409-452.

Peterson J. and Daniels H., (1992). Shrimp industry perspectives on soil and sediment management. In: *Proceedings of the Special Session on Shrimp Farming* (ed. J. Wyban) World Aquaculture Society, Baton Rouge, LA, pp.182-186.

Pham D., Della Patrona L., 1997. Shrimp aquaculture in New Caledonia: Zootechnical aspects. In: short communications and abstracts presented at the International Conference « Martinique 97 - Island Aquaculture and Tropical Aquaculture ». European Aquaculture Society, Les Trois Ilets, Martinique, French West Indies May 4-9, 1997.

Pillay T.V.R., 1992. Aquaculture and environment. *Bleckwell Scientific Publication*, Cambridge, 189 pp.

Pruder G.D., 1992. Marine shrimp pond effluent: characterization and environmental impact. *In: Proceedings of the Special Session on Shrimp Farming* (ed. J. Wyban) World Aquaculture Society, Baton Rouge, LA, pp.187-194.

Phillips M.J., Kwein-Lin C. and Beveridge M.C.M., 1993. Shrimp culture and the environment - Lessons from the world's most rapidly expanding warm water aquaculture sector. In: R.S.V. Pullin, H. Rosenthal and J.L. Maclean (Editors), Environment and Aquaculture in Developing Countries, ICLARM Conf. Proc., 31: 171-197.

Rajendran A.; Venugopalan V.K., 1977. Microbiology of nutrient regeneration: Part 3 - Experimental studies on marine nitrification. Indian J. Mar. Sci., 6, (1) 10-14.

Ray W.M. and Chien Y.H., 1992. Effects of stocking density and aged sediment on tiger prawn, Penaeus monodon, nursery system. Aquaculture, 104: 231-248.

Reymond H. and Lagardère J.P., 1990. Feeding rhythms and food of *Penaeus japonicus* Bate (Crustacea, Penaeidae) in salt marsh ponds: role of halophilic entomofauna. Aquaculture, 84: 125-143.

Rinj J.V., 1996. The potential for integrated biological treatment systems in recirculating fish culture. A review. Aquaculture, 139: 181-201.

Sandifer P.A., Hopkins J.S. and Stokes A.D., 1987. Intensive culture potential of *Penaeus vannamei*. J. World Aquacult. Soc., 18 (2): 94-100.

Seidman E.R., Lawrence A., 1985. Growth, feed digestibility and proximate body composition of juvenile *Penaeus vannamei* and *Penaeus monodon* grown at different dissolved oxygen levels. *Journal of the World Mariculture Society*, 16:333-346.

Schroeder G.L., 1987. Carbon and nitrogen budgets in manured fish ponds on Israel's coastal plain. *Aquaculture* 62: 259-279.

Sournia A., 1968. La cyanophycee *Oscillatoria* (*Trichodesmium*) dans le plancton marin: Taxonomie et observations dans le canal de Mozambique. *Nova Hedwigia* 15: 1-12.

Treguer P. and Le Corre P., 1975. Manuel d'analyses des sels nutritifs dans l'eau de mer. Utilisation de l'autoanalyseur II, Technicon R., Université de Bretagne Occidentale (Publisher), Brest, France, 110 pp.

Tsai C.K., 1990. Water quality management. *In: D.M. Akiyama* (Editor), Proc. Southeast Asia Shrimp Farm Management Worshop, Philippines, Indonesia, Thailand. 26 July-11 August 1989. Amarican Soybean Association, Singapour, pp. 56-63.

Tuckers C.S, Van der Ploeg M., 1993. Seasonal changes in water quality in commercial channel catfish ponds in Mississippi. *Journal of the World Aquaculture Society*, 24: 473-481.

Tunvilai D., Songsanchinda P. and Chaiyakum K., 1993a. Pollution loading of effluent from intensive tiger prawn culture ponds. Proceedings of the Thai Department of Fisheries Seminar, Bangkok, Thailand, 1993, 5 pp.

Tunvilai D., Songsanchinda P. and Chaiyakum K., 1993b. Variation of the sediment quality and quantity in intensive tiger shrimp culture ponds. Proceedings of the Thai Department of Fisheries Seminar, Bangkok, Thailand, 1993, 5 pp.

Veiler R.L., 1979. Rates of loss ammonia from water to atmosphere. J. Fish. Res. Board Can., 36: 685-689.

Wajsbrot N., Krom M.D., Gasith A. and Samocha, T., 1989. Ammonia excretion of green tiger prawn *Penaeus semisulcatus* as a possible limit on the biomass density in shrimp ponds. Bamidgeh, 41 (4): 159-164.

Wang J.K., 1990. Managing shrimp pond water to reduce discharge problems. Aquacult. Eng., 9: 61-73.

Wickins J.F., 1985. Organic and inorganic carbon levels in recycles seawater during the culture of tropical *Penaeus sp. Aquacultural Engineering*, 4: 59-84.

Wood E.D., Armstrong F.A.J. and Richards F.A., 1967. Determination of nitrate in sea water by cadmium copper reduction to nitrite. J. Mar. Biol. Ass. U.K., 47: 23-31.

Zimmerman A.R., Benner R. 1994. Denitrification, nutrient regeneration and carbon mineralization in sediments of Galveston Bay, Texas, USA. Mar. Ecol. Prog. ser., 114, 3, 275-288.

Task 2. Characterisation of ecosystems and follow-up of their evolution under the impact of shrimp aquaculture development in 3 geographic areas Mekong delta (Vietnam), Lampung Province (Indonesia) and North and Central parts of New Caledonia

Authors:	*O. Guelorget*	*University Montpellier II*
	A. Lefebvre	*University Montpellier II*
	J.L. M.Martin	*Crema-L'Houmeau*
	H.Lemonnier	*Ifremer - New-Caledonia*
	J. Fuchs	*Ifremer/Paris*
	A. Favry	*University Montpellier II*

in collaboration with:
ION scientists (Vietnam): *Dr. Nguyen Tac An and al*
BADC scientists (Indonesia): *Mr I.B.M. Suastika Jayal*

2.1. Introduction

2.1.1. Problematic

Indonesia and Vietnam aquaculture strongly developped in the past 15 years and became in both countries an economic activity of prime importance: 167 000 tons in 1994 and y ha used for shrimp culture in Indonesia, 36 000 tons and 250 000 ha in Vietnam in 1994. The main reasons of this rapid expension is due to the availability of sites presenting suitable geomorphological conditions.

Nevertheless, as stated in chapter 1, this rapid and uncontrolled development was often promoted by investors and decision makers without a clear idea of the necessary scientific knowledges to optimally select site, assess environmental impact and protect the environment in order to maintain production.

Though marine shrimp production continue to globally increase, this activity remains succeptible to environmental problems and managements. The degradation of site quality is succeptible to induce reduction in production efficiency with in some sites, large ecological damages and drastic collapses like we have observed during the study in Cirebon, Banyuwangi - North coast of Java or Cangio - North part of Mekong delta.

In order to substain the development of shrimp farming and protect suitable littoral environments, scientific investigations have to be carried-out on the organisation and functionning of littoral ecosystems. These research will allow in one hand to improve the selection and positionning of sites and in other hand to evaluate the degree of sensibility of each ecosystem to the impact of aquaculture development. Unfortunatelly, in most of the cases, the lack of scientific knowledges on ecology and hydrobiology of sites limits the capacity of integration of aquaculture on the global functionning of littoral ecosystems. In addition, the evaluation of the capacity of each site to support aquaculture in taking into account production capacity in relation with different ecological parameters is a very complex problem.

An ecological approach of littoral ecosystems, as proposed in the STD3 programme, should allow to better integrate the place of aquaculture in the environment in term of potentially of production and in term of evolution of the system, regarding particularly waste discharges.

2.1.2. Objectives

The general objective of task 2 is to study the place and impact of shrimp aquaculture in the main ecosystems of South East Asia and in Pacific region. It is proposed to achieve this objective in studying the correlation between aquaculture productivity and the main characteristics of coastal environments.

More specifically, four objectives have been defined:

1) Description of the organisation and functioning of representative coastal areas: delta, bays, coastal lines with mangrove or coral reef encountered in the region. Theses areas correspond to the principal ecosystems where aquaculture is potentially (site selection) or already well developped (management) in the whole region ;

2) Evolution of the studied sites under aquaculture pressure and identification and selection of the more significant parameters and bioindicators to take into account for improving environmental impact assessement ;

3) Correlation between the main environmental parameters and shrimp production for each site.

2.1.3. Expected outcome

This global approach of ecosystem characterisation and follow-up of their evolution under aquaculture pressure tend to integrate all the results obtained in the field of ecology, hydrobiology and economy in a synthetic scheme. This scale, already presented in WAS Symposium (Bangkok, 1996 ; Martinique, 1997) tentativelly position a site with or without aquaculture development in term of shrimp production potentiality in the main ecosystems encountered in the region.

2.2. Strategy

2.2.1. Site study

The different sites selected for the STD 3 study are characteristic of coastal environments in South-East Asia concerned by shrimps aquaculture development.

The sites are situated in estuarine or deltaic systems or along the coast following the shore line. These sites are always in communication with the sea. The hydrodynamic is mainly due to the tidal circulation and the flow of fresh water coming from the continent during the rainy season.

The sites are open on several seas, Java Sea, China Sea and Indian Ocean. These different seas have not the same water quality and the main physicochemical and biological characteristics act on the potential of productivity in term of shrimp culture.

The sites were choosen in regard to their representativity of the typical coastal ecosystem of the considered sea.

In Indonesia

- Sri minosari (South Sumatra): coastal aera with a very important aquaculture shrimp development. This site is typical of the north coasts of Java and Sumatra Islands (South of the Java sea). This coast is characterized by shallow waters, smooth hydrodynamic and poor mangroves.
- Merak Belantung (South Sumatra): wide bay open to the Indian Ocean with low development of shrimps aquaculture (only 60 hectares of ponds), without mangroves indicating a very light impact of continental pressure and a presence of corals along the coast. This site is a typical oceanic ecosystem.

In Vietnam

All the sites prospected are situated in Mekong Delta and represent all the characteristic situations in a deltaic ecosystem from the most continental parts to the more marine ones:

- Can Gio is the site with the lower impact of fresh water in the north of the delta.
- Tra Vinh situated in the middle part of the delta is highly under influence of continental pressure.
- Ca Mau in the south of the delta can be considered as a continental ecosystem considering the continental input and the maximum of the fresh water.

In New Caledonia

All the sites studied are located in west coast of New Caledonia and are situated in coralline ecosystems. These ecosystems are typical oceanic biotops.

The differences of the three sites are only in the geomorphological position inside the bay and the place of these sites in the organisation and the hydrological functioning of the bay.

Generally, the coastal areas interesting for shrimp aquaculture management are located in sedimentary ecosystems because the composition of soils. It is necessary to have a high pourcentage of clay to keep the water into the ponds. The accumulation of clay are dominating in the ecosystem under influence of continental inputs and are situated at the limit between continent and sea.

This geographical position introduces the great problem of the water quality in relation with the shrimp production, the impact of the shrimp farming on the environment and the evolution of the ecosystem.

In fact, the place and the role of aquaculture development depend on the geomorphology of the site, the organisation and the functioning of the ecosystems supporting the shrimp management.

2.2.2. Sampling strategy

The strategy of study was defined in order to describe the organisation and the functioning of the selected ecosystems and to evaluate the impact of aquaculture management.

The stations of study were placed along transects established in different position depending on the characteristis of each ecosystems. In the case of ecosystems represented by a open coastline and/or semi-closed systems, where the hydrological and biological organization is parallel to the coast-like Sumata coast in Java sea, the stations of study are placed olong transects established perpendicularly to the coast. When closede bays are concerne, it is necessary to consider the whole ecosystem and to cover the total surface of the bay in dispatching the stations (New Caledonia). In a deltaïc complex like the Mekong delta, the strategy oblige to consider the hydrodynamic network from the open sea to the most continental zone as the system is due to the balance between continental pressure and mariine water influence according to the tidal movement. In the Mekong delta, the whole system has been investigated from Cangio (North) to Ca Mau (South) through Tra Vinh (central part). The detailed locations of sampling stations are described for each site in 2.4.

The climate is typical of South East Asia with two alternative marked seasons. In Indonesia the dry season extends from april to october and in Vietnam from october to may. In both case, two campaigns have been conducted each year during dry and rainy season. For logistical reason and due to the dificulty to accessto a number of site in Mekong delta, most of the research has been carried out in Cangio (North) and Tra Vinh (center). The site of Ca Mau has been investigated only one time in late 1996. In New-Caledonia where the seasonnal rythm is less marked, it has been chosen to organize the two surveys at the same season (december).

It has to be notice that most of the field work has been realized in strong collaboration between EU and asian partners in order to exchange methodolgies and fruitfull their local knowledges on these complex ecosystems.

The main parameters studied concerned waters and sediments. Hydrobiological parameters are instantaneous descriptors which have great variations in short term. Their repartition depict the dynamic of waters inside the ecosystem. Sedimentological parameters integrate the environmental conditions in a long term and their repartition give an excellent view of the organization of the ecosystems.

Sampling and measurements in the water column are always realized at the surface and just above the bottom, in the deepest zones. In some stations, the sampling concerned the whole water column to precise the vertical gradient and to determine the eventual stratification of the water body.

2.2.3. Parameters of study

The main objective of the study is not to describe with precision each ecosystem but the aim is to analyse the importance of a number of parameters as descriptors of the organization and functionning of typical coastal zones and their relations with aquaculture. For that reason, a limited number of repersentative parameters have been selected to determine the interelations between the quality of coastal environment and the production of shrimps.
These parameters are:

a) hydrobiological parameters:
  - Physicochemical parameters: T°C, Salinity, dissolved oxygen, PH
  - Suspended matter and Organic matter
  - Carbon and nitrogen (C/N ratio)
  - Chlorophyll (a) biomass (chlorophyll a phaephophytin)
  - Sulfato reducer bacteria.

b) sedimentological parameters:
- Granulometry
- Carbonates
- Organic matter
- Carbon and nitrogen
- Sulfato reducer bacteria.

2.3. Methodology for site studies

The usual hydrological parameters (pH, conductivity, dissolved oxygen content, temperature) were mesured on the field using a multiparameter probe HORIBA.

Water samples were collected for phytoplankton analyses and measures of the following parameters.

- Total suspended matter (seston)
- Suspended organic matter by fire loss at 450° C
- Suspended mineral matter
- Carbon and nitrogen (Hedges and Stern, 1984).

The abondance of phytoplankton was evaluated by the chlorophyll *a* biomass, and its degradation level by the percentage of phaeophytin. Both were measured by fluorimetry following the method described by Neveux (in Aminot et Chaussepied, 1980).

The structure of phytoplanktonic communities was analysed by flow cytometry (Phinney and Cucci, 1989 ; Platt, 1989 ; Yentsch and Horan, 1989 ; Troussellier *et al.*, 1993).

Fresh samples were fixed with paraformaldehyde (0,5 % final concentration) and were kept in the dark at 0° C (Vaulot *et al.*, 1989). Samples were analysed with a cell analyser equiped with a mercury lamp (ACR 1 400 SP, Bruker Spectrospin, Wissembourg-France).

For phytoplankton, light excitation wavelength used was 470-490 nm, while green and red fluorescences were separated with a LP640 nm dichroic filter and selected using a BP580+/-20 nm and a BP680 +/- 20 nm filters. Duplicate sample volumes were measured for each stations and the data stored in data mode and list mode.

Four parameters per cell (forward and wide angle light scatters, green/yellow and red fluorescences) were recorded on a 3.3 decade logarithmic scale mapped onto 256 channels. Instrument calibration was achieved with 1 mm fluorescent beads (Polysciences, Warrington, PA, USA). Data collected on a HP-compatible computer were analysed with Flower software (Bruker-Spectrospin). Phytoplanktonic subpopulations of the samples were identified according to their light scatter (related to cell size) and their green/yellow and/or red fluorescence due to the presence of natural pigments (biliproteins, chlorophylls).

The number of cells and the mean values of the cellular parameters for each subpopulations were computed after conversion of the logarithmic scales to linear ones. Used as an internal standard (because their light properties are stable), 1 mm fluorescent beads (Polysciences) permit to normalize the mean subpopulation parameters through division by the corresponding parameters measured on the beads.

The study of phytoplanktonic populations, thus characterized by their relative size and pigment contents, could be extended to large areas to evaluate their spatial and temporal evolutions.

Samples of sediment were collected during the July 1995 study campaign. The sampling stations cover the entire operating unit.

Only the superficial part of the sediment, corresponding roughly to the two first centimeters, is preserved in alcool on the site. At the laboratory, 50 cm^3 of these samples are washed in a 50 cm sieve, then dried in an oven.

Foraminifera are isolated by flotation on carbon tetrachloride. After the assessment of the total number of tests, the relative number of each species is estimated in 100 to 300 individuals, according to the specific richness of the sample.

Counting the total number of species of each sample completes this analysis. Using the same initial volume of sediment (50 cm^3) allows for a quantative comparison.

Observations are realized on total populations (biocoenose and thanatocoenose). Indeed, as sampling concerns only the superficial part of the sediment, we can conclude that, considering the high sedimentary speed, alive and dead individuals *in situ*, are part of the same present community.

2.4. Results

2.4.1. Indonesian ecosystems

2.4.1.1. Introduction

Two sites have been studied in South Sumatra, in the Indonesian archipelago (**fig. 17**). These are the bays of Sri Minosari and Merak Belantung. Biogeological survey has been realized during 4 years, from 1992 to 1995 (**table 34**).

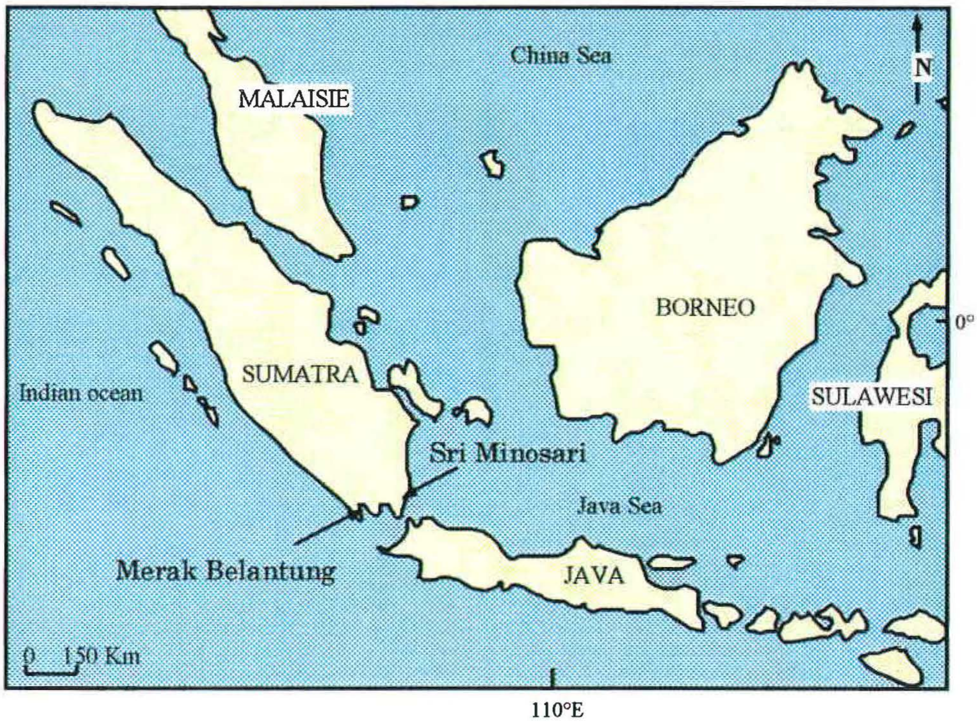


Figure 17. Location of the site of Sri Minosari and Merak Belantung in the Indonesian archipelago.

Table 34. Dates of sampling missions in Indonesia.

Dates	Sites
October 1992	Merak Belantung - Sri Minosari
February 1993	Merak Belantung - Sri Minosari
October 1993	Merak Belantung - Sri Minosari
June 1994	Merak Belantung - Sri Minosari
May 1995	Merak Belantung - Sri Minosari
December 1995	Merak Belantung - Sri Minosari

2.4.1.2. Merak Belantung

Description

Merak Belantung, located at the outlet of the Sonde strait, is in permanent communication with the Indian ocean (**fig. 17**). This large bay is deep, its bathymetry exceeds 25 meters in the central part. Furthermore, the coastal plain is narrow and the continental platform is reduced.

Coral reefs that colonize all the bottom of the bay bear witness to the importance of the renewal of the bay by oceanic waters.

The bay supports currently about 80 ha of intensive aquaculture basins of shrimps "*Penaeus monodon*" distributed on the periphery of the basin.

Sampling stations, (9 or 27 according to the mission), are divided all along a radial (**fig. 18**) from the sea (station 1) towards the coastal line (station 9 or 27).

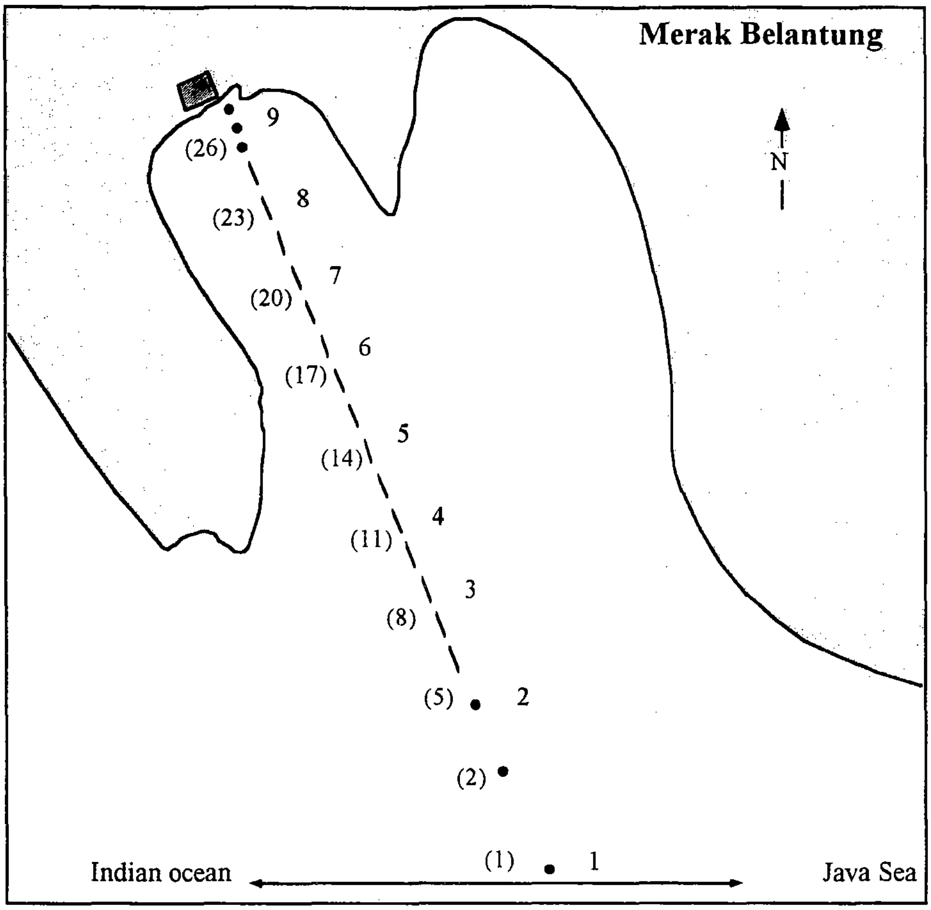


Figure 18. Location of sampling stations in Merak Belantung bay (South Sumatra).

Temperature and salinity. Whatever the season, the temperature fluctuates between 28 and 31° C in all samplings.

Salinities vary from 30 to 36 ‰. Extreme values correspond to continental shores, where dilution occurs by precipitations during the rainy season and evaporation during the dry season. Nevertheless, salinity horizontal gradients are weak in comparison with other coastal ecosystems.

pH. The pH is approximately 8.5 value close to the marine water one. The variations of pH are very weak in time as in space.

Dissolved oxygen. Measures recorded in 1992 and 1993 point out concentrations in dissolved oxygen close to 10 $mg.l^{-1}$. More recently, in 1995, mean values are about 6 or 7 $mg.l^{-1}$ land reach 10 $mg.l^{-1}$ only locally at the edge of the bay when the depth is inferior to 1 meter.

Suspended matter - Organic matter. During the dry season, suspended matter is relatively high (14 to 25 $mg.l^{-1}$) while contents in organic matter are still weak (3 to 6 $mg.l^{-1}$). Concentrations are stronger in surface waters but the contribution of the organic matter to total suspended matter is in general more important at the bottom **(fig. 19)**.

In the rainy season contents in suspended matter (SM) and in organic matter (OM) are close to 6 and 2 $mg.l^{-1}$ respectively. These values are clearly weaker than in the rainy season, nevertheless the organic matter percentage is slightly higher: from 22 % in October to 33 % in February. A vertical distribution appears, surface waters are more loaded. Two zones are identified, an external zone communicating with oceanic waters (SM: 4 and OM: 1 mg.l^{-1}) and an internal zone where concentrations in suspended matter and in organic matter are significantly higher (SM: 15 and OM: 3 mg.l^{-1}), at the continental extremity of the bay.

The slope of the regression line of the content in organic matter in function of suspended matter is practically the same for these two periods of the year. Organic matter and suspended matter increase globally in same proportions in February and October **(fig. 20)**.

It is only at the end of the rainy season, during May, that an imbalance appears. Near the shore suspended matter exceeds 40 mg.l^{-1} and the organic matter contribution is about 60 % **(fig. 20)**. It is the only period of the program when the impact of the continental domain is visible from these parameters in Merak Belantung.

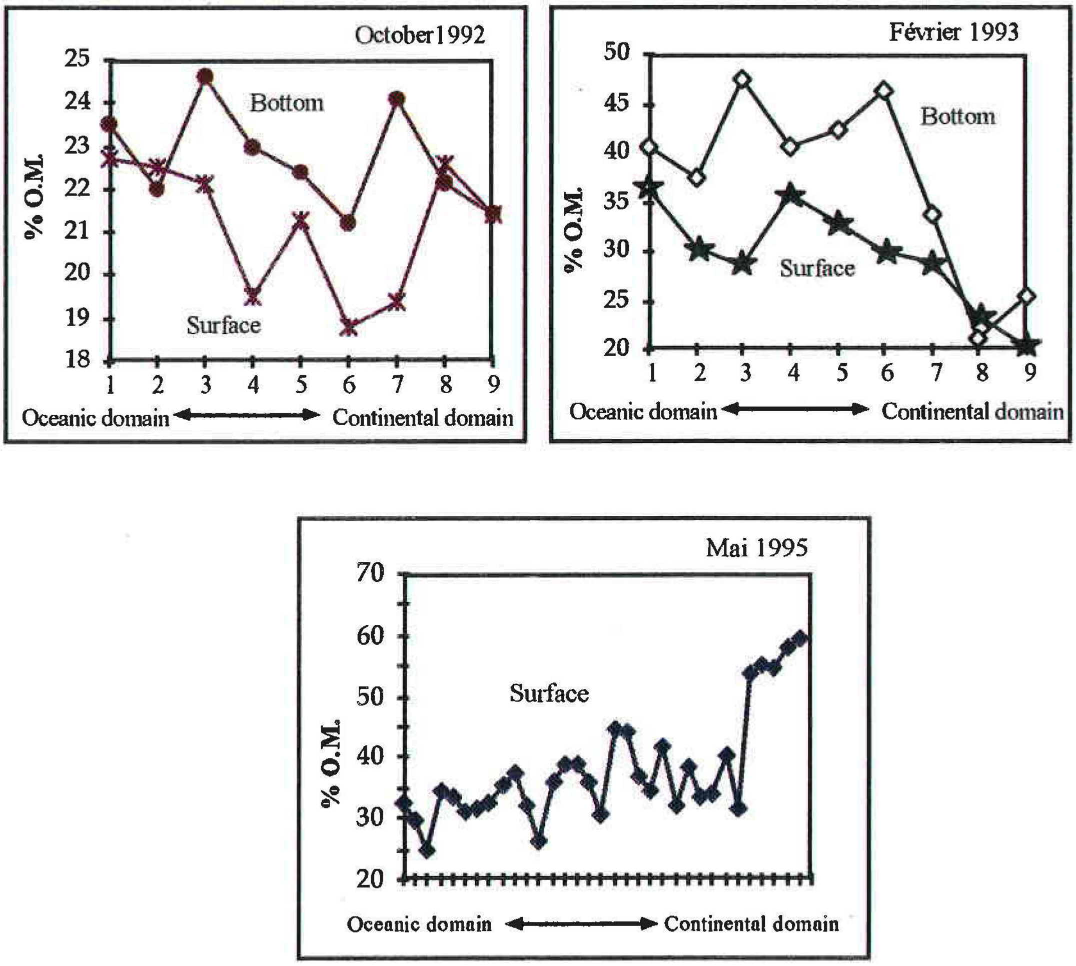


Figure 19. Contribution of the organic matter to the total suspended matter.

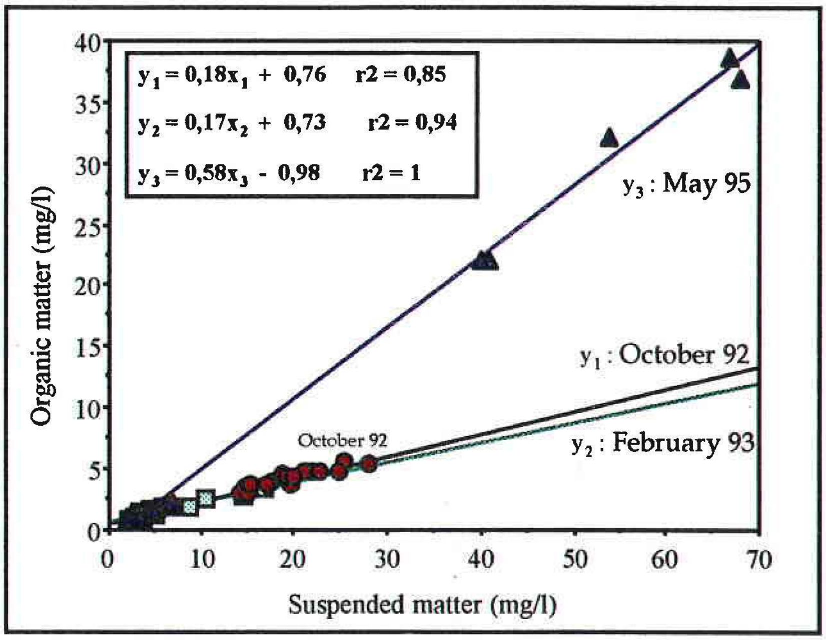


Figure 20. Variations of organic matter concentration according to total suspended matter.

Phytoplankton:

Chlorophyllian biomasses. Mean values of chlorophyllian biomasses are inferior to 1mg/m^{-3} whatever the season, when the depth exceeds 0,5 m. This value is relatively weak, it corresponds to a low trophic level. This is confirmed by the mean concentrations in phaeophytin which exceeds 2 mg.m^{-3} only at the end of the rainy season **(fig. 21)**.

At the coastal edge, under the continental enrichment pressure, values are clearly higher (4 mg.m^{-3} in May or 7 mg.m^{-3} locally in October) and they increase again in waters from rejects of the aquacultural farm or in the mangrove zone.

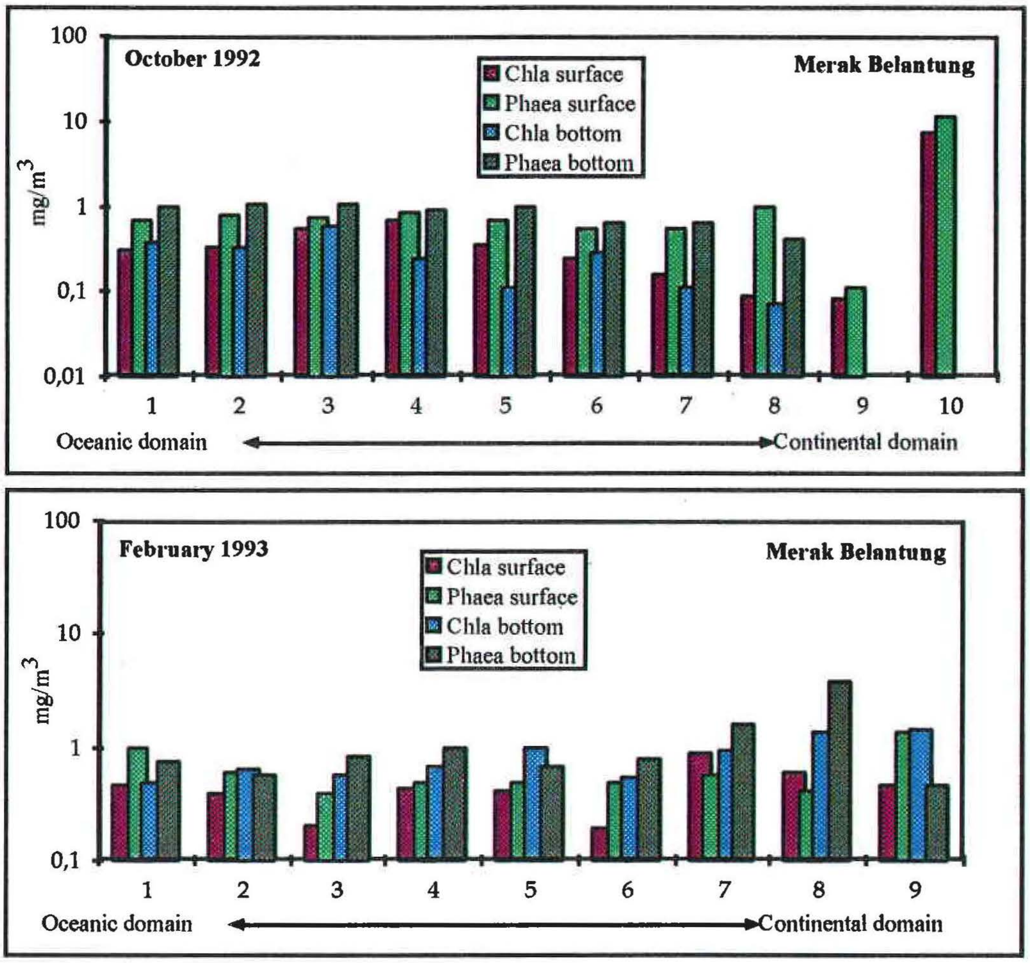


Figure 21. Variations of chlorophyll a and phaeophytin biomasses.

Ataxinomic composition. The analysis of chlorophyllian plankton by flow cytometry depicts four main populations of cells **(fig. 22)**. The first one (S3) is composed of small cells with a relatively low content in chlorophyll. The analysis reveals the presence of a supplementary pigment non chlorophyllian, the phycoerythrin. These observations allow to assimilate these cells to cyanobacteria.

The two types C1and C2 are composed of larger cells with a higher relative chlorophyll content.

An additional population (C3) may be evidenced when comparing the relative cell sizes and the relative chlorophyll contents of phytoplanktonic cells **(fig. 22)**.

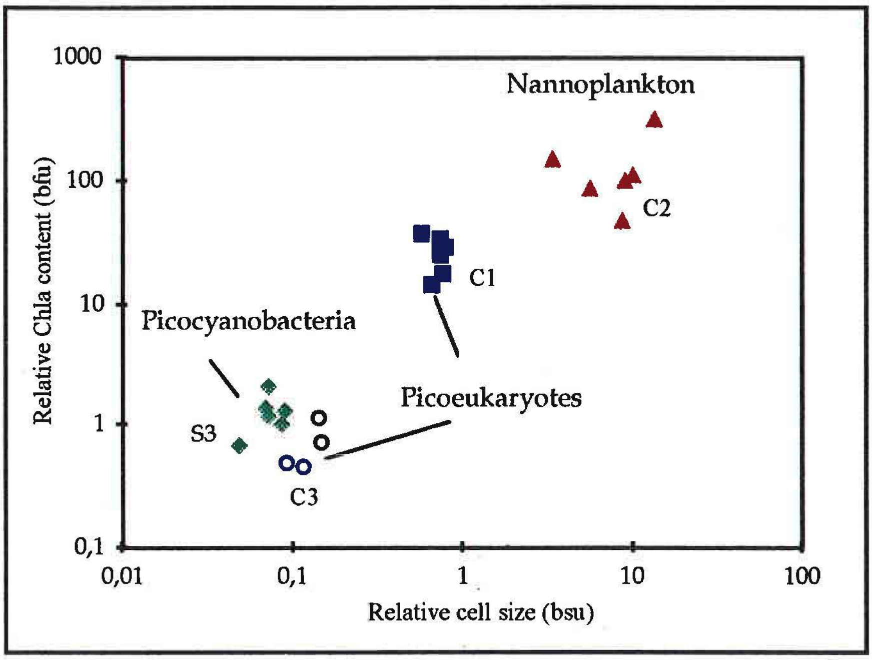


Figure 22. The different phytoplanktonic populations characterized by their light scatter and pigments properties normalized with 1 micrometer beads.

The comparison of relative cell sizes normalized with 1 micrometer beads, to those of phytoplanktonic populations from other paralic ecosystems, show that types S3, C3 and C1 probably belong to the picoplankton. Their size is between 0,2 and 2 mm.

Picoplankton is far more important than the bigger populations in the whole bay **(fig. 23)**. Outside the bay more than 98 % of the population is represented by cyanobacteria from an oceanic origin. Their contribution decreases (88 % then 82 %) inside the ecosystem. At the same level appears a new population of eukaryotes. The percentage of these eukaryotes exceeds 70 % in the aquacultural farm and the adjacent mangrove zone. Therefore, their presence in the bay is induced by the continental pressure.

In shrimps basins the contribution of cyanobacterias to total density increases again. Nevertheless, it seems to be a population peculiar to basins as in the farm of Jepara on the island of Java (Guelorget *et al.*, 1995).

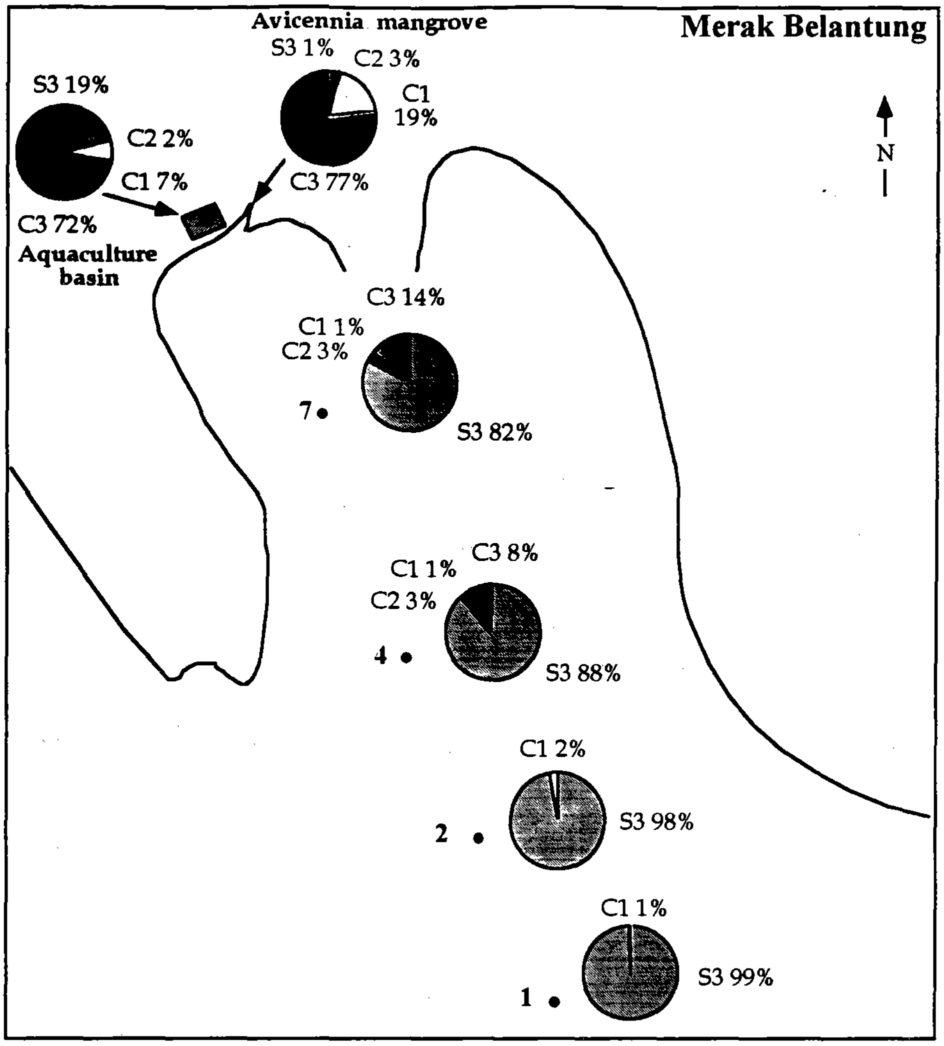


Figure 23. Representation of phytoplanktonic assemblage of Merak Belantung.

Sediments. Sediments of Merak Belantung are coral white sands. The organic matter percentages are ranged between 2 and 3.5 %. These values are weak and show that the organic matter possibly rejected by the farm is well assimilated by the ecosystem.

Conclusion

Merak Belantung bay follows as a marine system where gradients are weak and the continental influence is not pronounced and limited to the most coastal edge. Only the study of phytoplanktonic populations by flow cytometry allows to detect a light modification of waters between the exterior and the interior of the bay.

The distribution of the other biogeological parameters shows that this bay is a relatively homogeneous ecosystem where the rythm of seasons (specially rains) has a punctual action and limited in time. There are 40 aquacultural farms that occupy a surface of 140 ha and correspond to a production of 498.3 tons, given 1.730 kg/ha/crop. The impact of shrimp culture is not very visible and does not induce notable modifications in the organization and the functioning of the system.

2.4.1.3. Sri Minosari

Description
The bay of Sri Minosari is edged with mangroves, and merges into the Java sea (**fig. 17**). It is a shallow bay where semi-intensive aquaculture covers approximately ten thousand hectares.

The coastal plain is far larger than on the versant of the Indian Ocean and the depth of the Java sea remains Java weak. The hydrographic system is dense, which explains important fresh water contributions to Java Sea waters.

The mangrove has been reduced because of the settlement of aquacultural shrimps basins and only a narrow part of the initial green belt still subsists.

Nine study stations have been selected from the sea (station 1) in direction of the shore (station 9) (**fig. 24**).

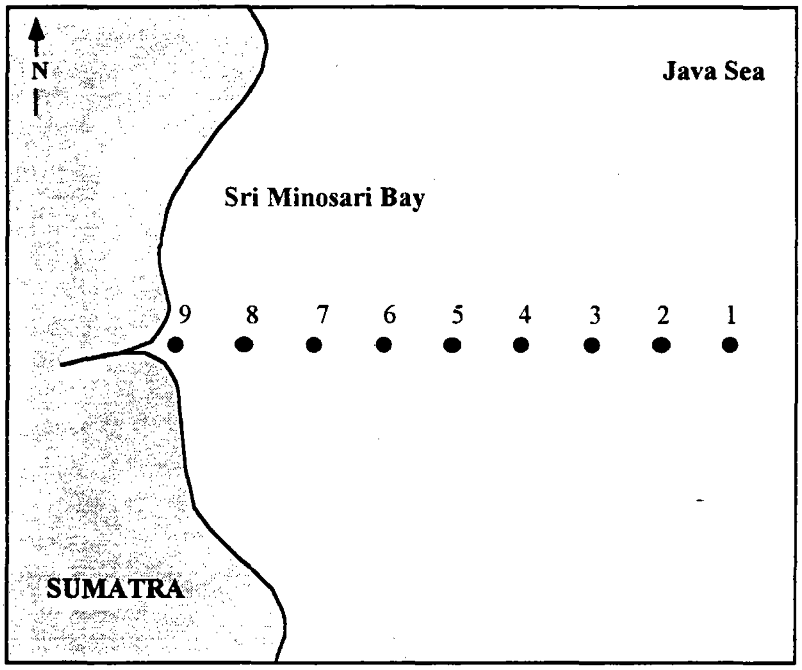


Figure 24. Location of sampling stations in Sri Minosari (South Sumatra).

Temperature and salinity. Temperatures range between 28 and 32° C. Spatial variations are very weak, waters seem very slightly warmer at bay edges (**fig. 25**). Waters are hotter at the surface than at the bottom.

During the dry season, the salinity is close to 33 ‰ . Differences exist horizontally and vertically. Nevertheless, it is only in rainy season that a decreasing gradient of salinity is established between the sea and continental margins (**fig. 25**).

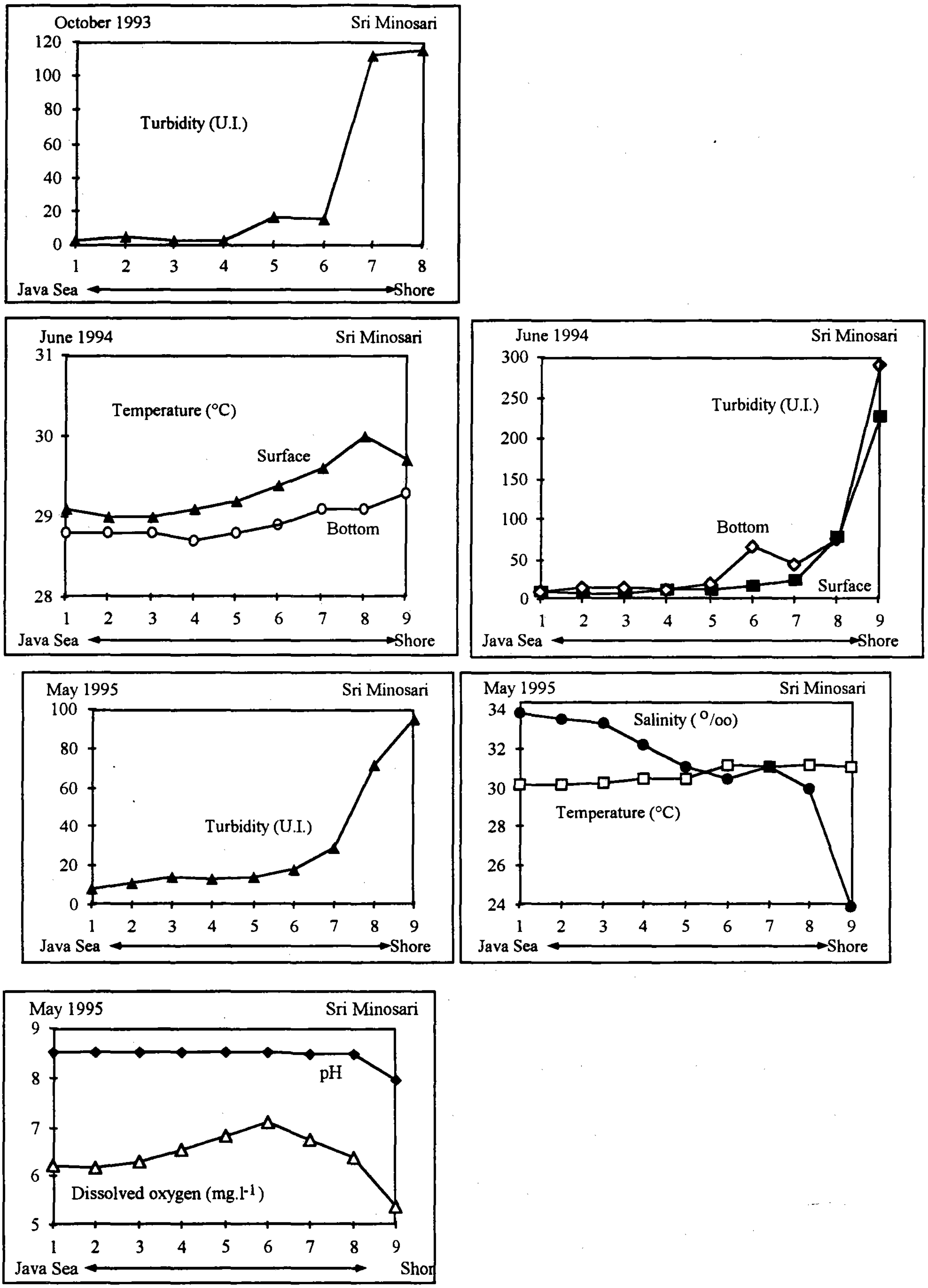


Figure 25. Spatial variations of turbidity (UI), salinity (‰) dissolved oxygen ($mg.l^{-1}$), temperature and pH in Sri Minosari Bay waters (South Sumatra).

pH. Values of pH on the whole bay and all along the water column are characterized by weak fluctuations. At the surface and at the bottom, the mean pH is about 8-8.5. Minimal values (< 8) are generally closest at the shore.

Dissolved oxygen. The concentration of the oxygen dissolved in the waters of the bay of Sri Minosari is variable. It oscillates around a value of 8.9 mg.l^{-1} in October. In June its repartition describes the weakness of vertical mixing, with a difference of 3 mg.l^{-1} to the detriment of the bottom. This situation does not prolong along the year since it is the only samplig time when this phenomenon appears.

The horizontal variability is weak but it appears to be a progressive temporal evolution. From 1993 to 1995 concentrations in oxygen have regularly decreased and in December 1995 they do not exceed 6 mg.l^{-1} (**fig. 26**).

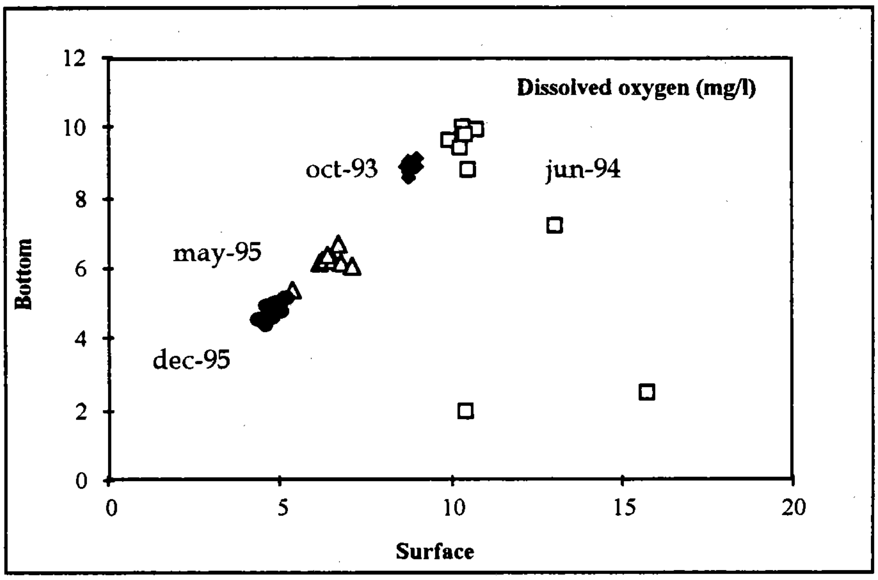


Figure 26. Temporal variations of dissolved oxygen concentrations.

Suspended matter - Organic matter. Quantities of suspended matter are very important in the coastal border, particularly in the rainy season, it is a direct consequence of the importance of continental contributions during this season (**fig. 27**). Nevertheless, in the dry season, quantities of suspended matter remain high.

Globally, suspended matter is more important on the bottom, this is in connection with the weak hydrodynamic of the milieu that allows only a partial homogenization of this shallow bay.

Average rates of organic matter range from 8 to 28 %, whatever the season. They are slightly weaker in the near paralic, where continental contributions seem constituted by an important mineral fraction.

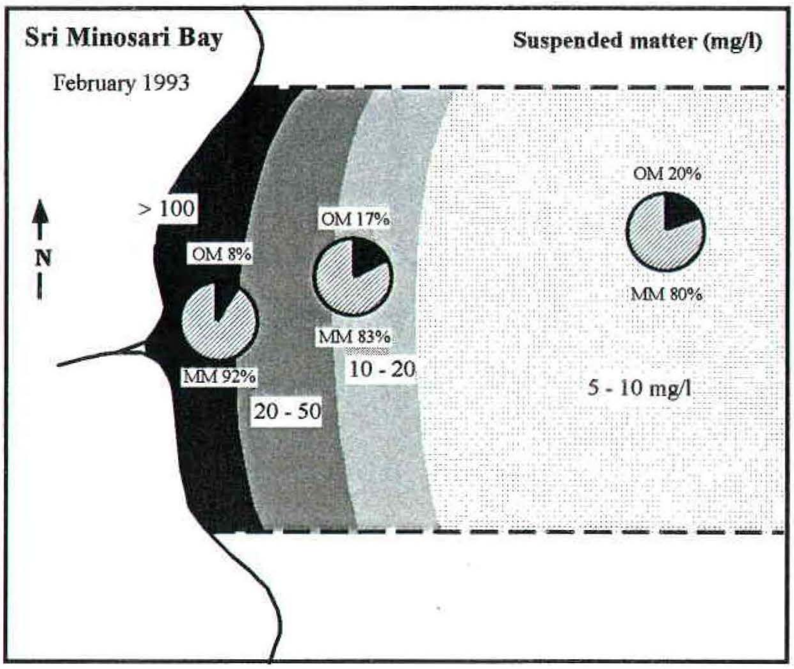


Figure 27. Repartition of suspended matter in Sri Minosari Bay - Contribution of organic matter.

During the dry season, represented in graph 12 by the month of October 1992, mean of suspended matters is close to 16 $mg.l^{-1}$ at the reference station in the Java sea. Near the shore, they exceed 100 $mg.l^{-1}$. The organic matter represents an average situated either between 8 and 22 % or bretween 3 and more than 10$mg.l^{-1}$.

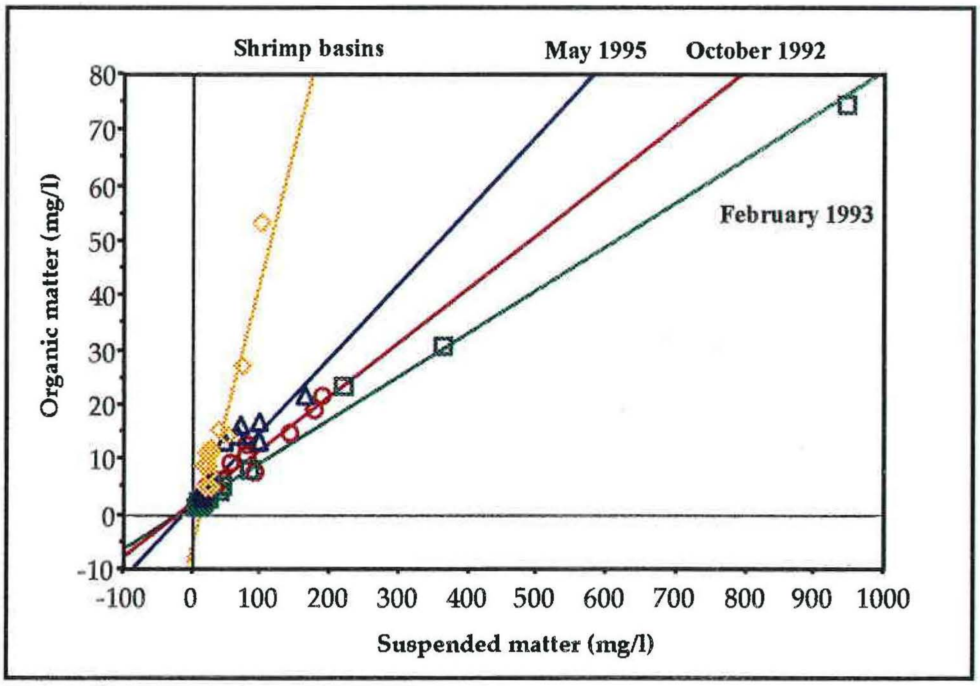


Figure 28. Relations between organic matter and total suspended matter evolution.

During the rainy season (February 1993), suspended matter increases roughly (max: 944 $mg.l^{-1}$ at station 9) while the increase of the organic matter is more moderate (max: 75 $mg.l^{-1}$), which explains why the slope of the regession line is weaker.

At the end of the rainy season (May 1995) the slope is greater. At stations close to the beach, where suspended matter is always mors important, the contribution of the organic matter has increased (mean: 21 %).

In the aquacultural farm in basins nearest to the pumping station, the organic matter percentage is 17 % (SM 29: $mg.l^{-1}$) and in farthest basins half of the suspended matter is of organic origin.

Organic carbon - Organic nitrogen. During the dry season, the value of the ratio C/N in whole basin is situated between 4 and 6 (**fig. 29**). It evolves from the sea towards the shore according to a polynomial function of order 3. Maximal values correspond to the shallower stations which are also directly under the influence of continental contribution.

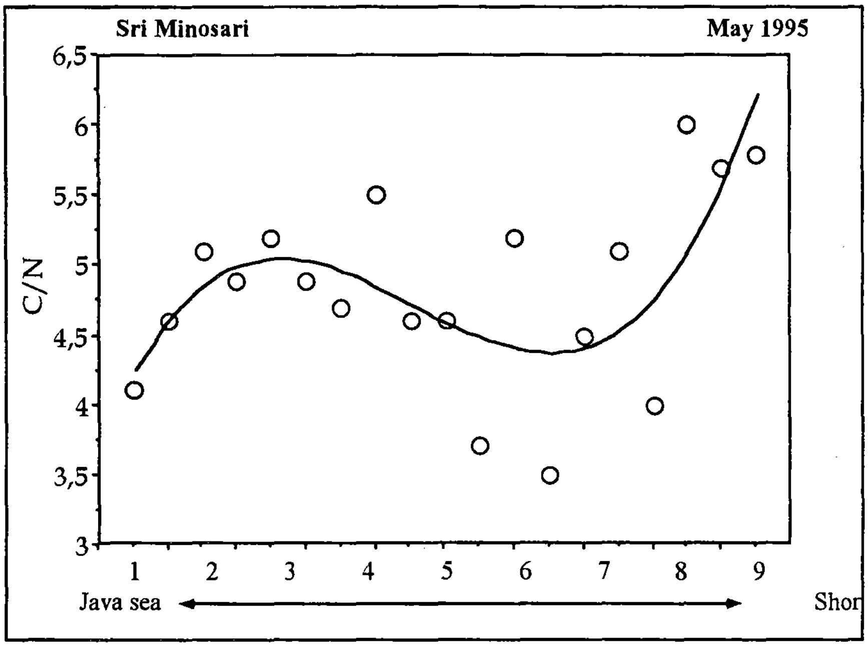


Figure 29. Spatial variations of C/N ratio.

Phytoplanktonic biomasses. Globally, there is a permanent positive gradient of the phytoplanktonic biomass and of the percentage of phaeophytin from offshore stations towards the edge of the bay (**fig. 30**). These gradients are not disturbed by tidal cycles or by seasonnal changes. They still exist whatever the season and the tide.

Therefore, in the vicinity of the aquacultural installation, an increase of chlorophyllian biomasses and a rapid degradation of populations which are under unfavorable conditions (turbidity, mixing waters, stratification...) occur.

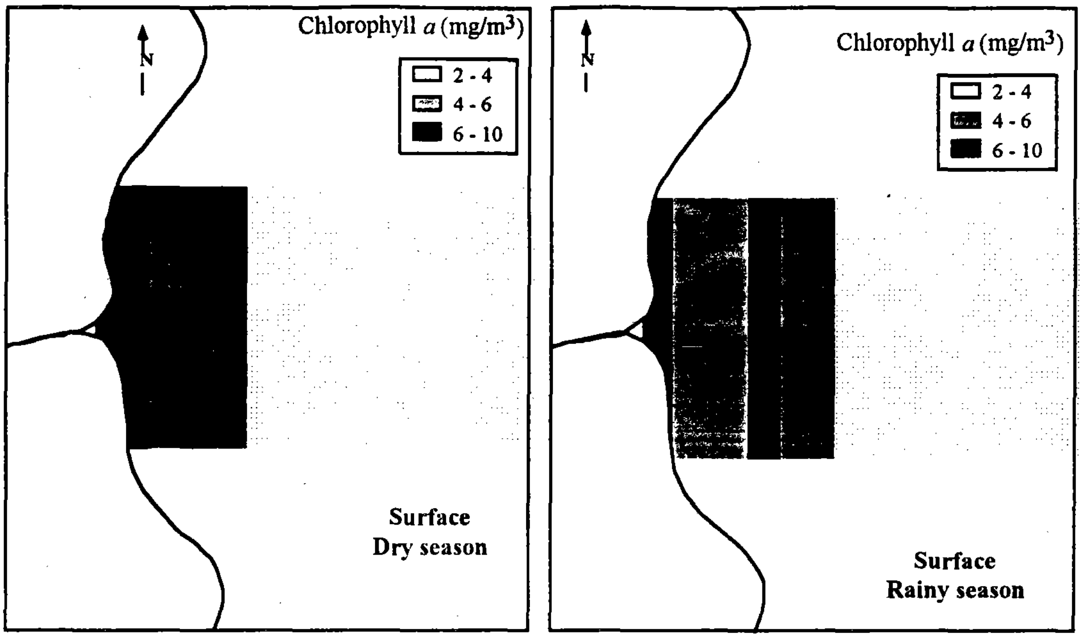


Figure 30. Spatial evolution of chlorophyllian biomasses in Sri Minosari.

Sediments. Variations of contents in organic matter in the sediment are situated between 3 % and 5 % in the dry season and between 2 % and 9 % in the rainy season. In December contents in organic matter of the bay's edge are higher than those from the sea. In May, the percentage does not present significant variations (**fig. 31**), except for a slight increase at station 5, in the center of the bay. Therefore a translation of the organic matter occurs from inshore to offshore during the season of rains.

In December, from station 1 to station 7 the ratio C/N varies between 6 and 7.5. This value corresponds to the sedimentation of phytoplanktonic populations of various sizes (Schuman, 1978 ; Hedges *et al.*, 1988). At the extremity of the bay (station 9) the value increases roughly, the origin of the organic sediment matter is no longer exactly the same; it can concern, for example, labile organic matter.

In May, the ratio C/N is weaker. It is 5 in sea and decreases to a value close to 3 near the shore. That kind of decrease can appear in an ecosystem when the quantity of organic wastes from non anthropic origin increases.

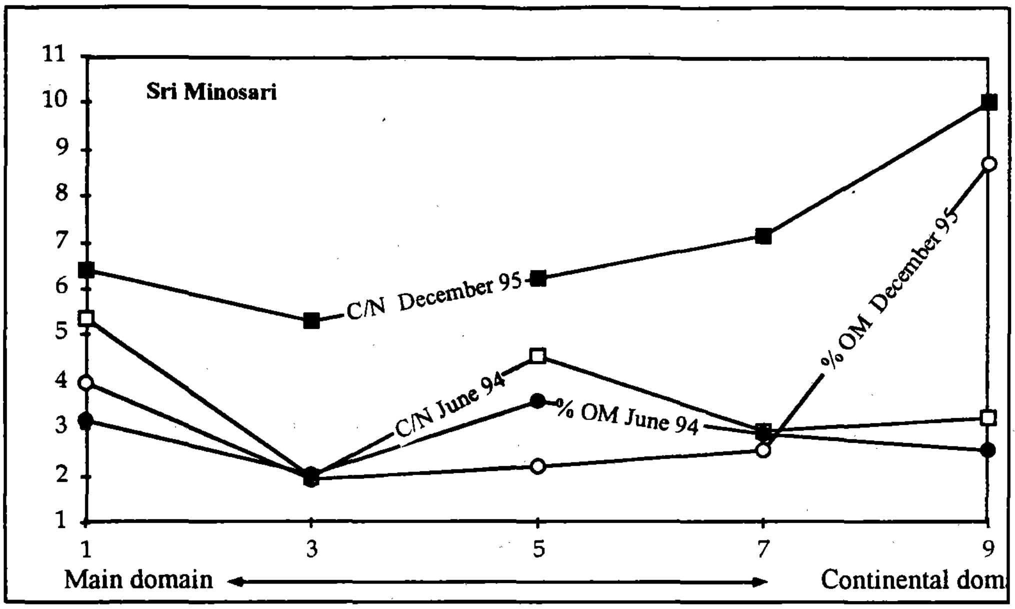


Figure 31. Variations of C/N ratio and organic matter (%) in the sediments of Sri Minosari.

Conclusion

Finally, this coastal ecosystem is temporarily stable. The spatial variability superposes to the seasonal variability but the stability is a long term one. Compared to the bay of Merak Belantung, the milieu seems to be submitted to an organic enrichment. The evolution of organic matter in waters is significant but there is no obvious relation to a possible discharge but rather a seasonnal variation induced by precipitations.

There are more aquacultural farms than in Merak Belantung (1 159 farms given 1 962 ha), the annual production reaches 2 021 tons, 515 kg/ha/crop.

Continental pressure appears through the horizontal gradients. They shows the local enrichment of water (phytoplanktonic biomasses ...) and of sediments near the shore, in the zone under aquacultural discharge influence. The low value of the percentage of organic matter can be explained by an increase of bacterial mineralisation, especially carbonate production.

2.4.2. Vietnamese ecosystems - Mekong deltaic ecosystem

2.4.2.1. Introduction

The Mekong delta, located in the most South-eastern part of the Eurasian continent is called a Cenozoic basin and was filled progressively by fluviatile and marine sediments. In the middle Pliocene, transgression reached the maximum level, and the sea covered Ha Tien and Chau Doc. About 2 millions years ago most of the delta emerged.

The river basin has a dentritic form, the flow is 500 km3/year with 70 millions tons of sediments.

Tidal regime in the coastal sea of the studied region is irregular semi-diurnal.

The mekong river is divided in two branches: the Tien river and the Hau river. The Hau river flows to the ocean through 3 main estuaries, the Tien river which has the most important water capacity (over 79 %) has six estuaries.

Sampling

Sampling in Viet Nam took place from November 1994 to April 1997, at flow and ebb tide **(table 34)**.

Dates	Sites
7-17 November 1994	Cangio - Vungtau
10-16 May 1995	Cangio - Vungtau
9-15 July 1995	Cangio - Vungtau
10-16 December 1995	Cangio - Vungtau
6-12 May 1996	Cangio - Vungtau - Travinh
23-30 November 1996	Travinh
10-20 April 1997	Camau

Table 35. Sampling periods.

Climate

The region of Can Gio is under the influence of a subequatorial monsoon. The climate is marked by two main seasons, a dry season from November to April and a rainy season from May to October.

Mean annual precipitations are about 960 mm at Can Gio, and 90 % of these precipitations are concentrated between June and October.

The mean air temperature varies between 26 and 28° C according to the season.

Dominant winds blow from the North-east and Southeast and their average speed varies between 1 and 5 m/ s from October to April.

The tidal amplitude oscillates between 3 and 4 meters during the spring tide and 1.5 to 2 meters during the neap tide. The cycle of tide is semi-diurnal. In the region of Can Gio, and especially in Vung Tau, an exaggerated elevation of the water level in the deltaic system occurs during some periods. This phenomenon is induced by the winds that push coastal waters inside the hydrographic system. This water tide begins in September, reaches its maximal height in December and is back to the normal level in February.

Land use

Land used by agriculture covers approximatively 2 460 000 ha. Water surface used for aquaculture increases quickly while forestation land is decreasing. Uncultivated land covers 655 788 ha in 1996, which means 16,6 % of total area.

Table 36. Areas and productions of sites studied in Vietnam.

Site studied	Farming area ha	Shrimp production tons
Vung Tau	3170	412
Cangio	3720	505
Tra Vinh	15545	3201
Camau	105519	27700

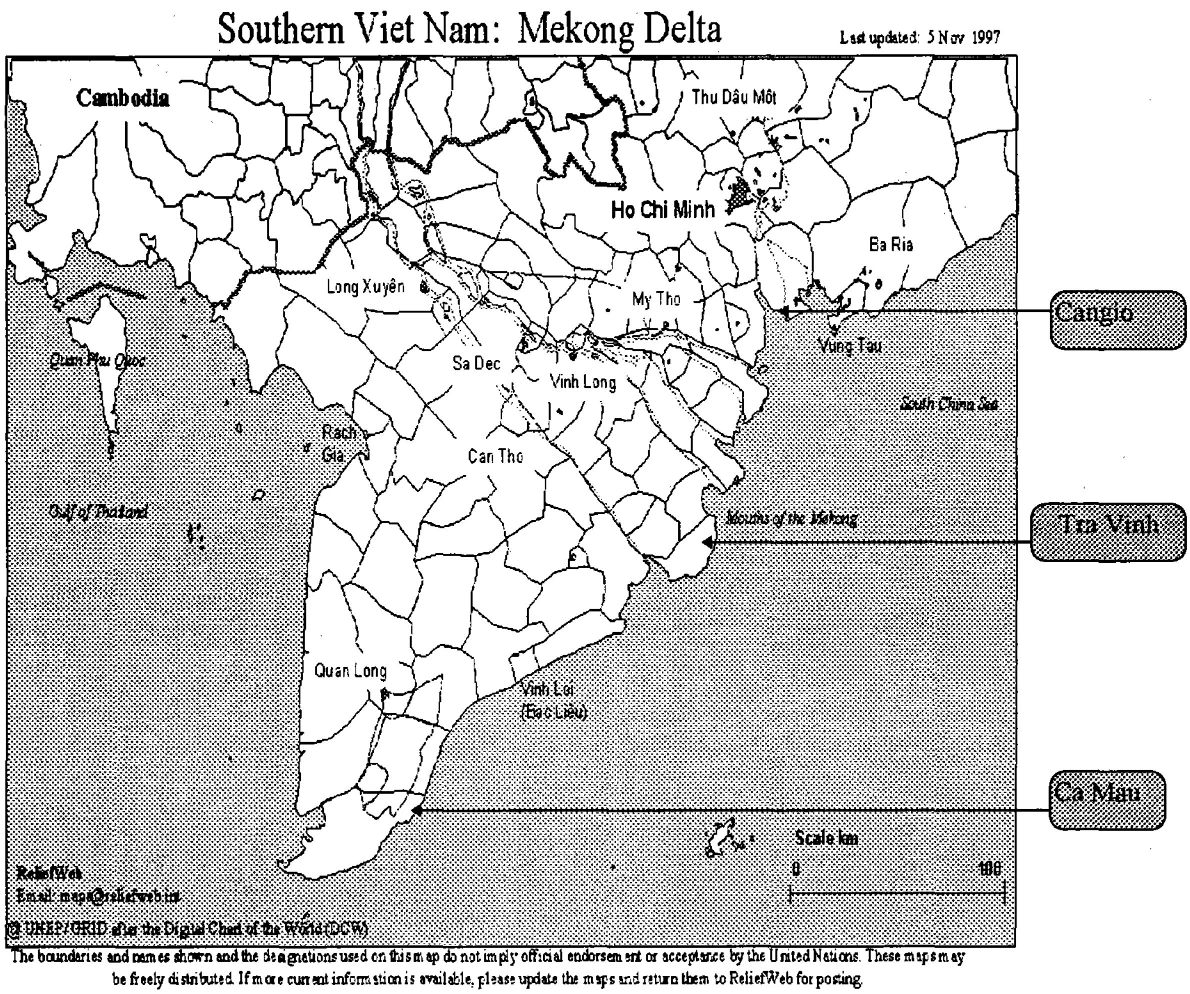


Figure 32. Location of studied sites in Viet-Nam.

2.4.2.2. Cangio delta

Description

Study area. The Mekong is a river 4220 km long of which 220 km are in the Vietnam. It takes its source in the Tibet and its delta situated to the south west of Hô Chi Minh-City separates in to nine branches called the Nine Dragons. The site of the study concerns the north zone of the Mekong delta limited by agglomerations of Can Gio and Vung Tau.

This north part of Mekong river is a typical unit which includes a mangrove ecosystem with some types such as Avicennia fringing along the margin of estuary mouth, coming after Rhizophora along the river then Nypa at the upper part of Ngabay river.

12 stations were sampled in the Mekong estuary (**fig. 33**). Station 1 is located at the Mekong river mouth, inside the bay, wide off Can Gio's cape. Stations 2, 3, 4 and 5 are implanted in the main river and spread regularly upstream, from Vinh Ganh Rai nearly to Song Nga Bay. Station 6 is situated in the mouth of a tidal channel that opens on the river between stations 4 and 5. Stations 7, 8 and 9 are implanted upwardsr in the same channel, station 9 is in the mangrove edging the channel. Three other stations have been implanted at the edge of the bay for the study of sediments and notably of foraminiferas. Two stations are located in the intertidal zone and a third in the mangrove coastal zone.

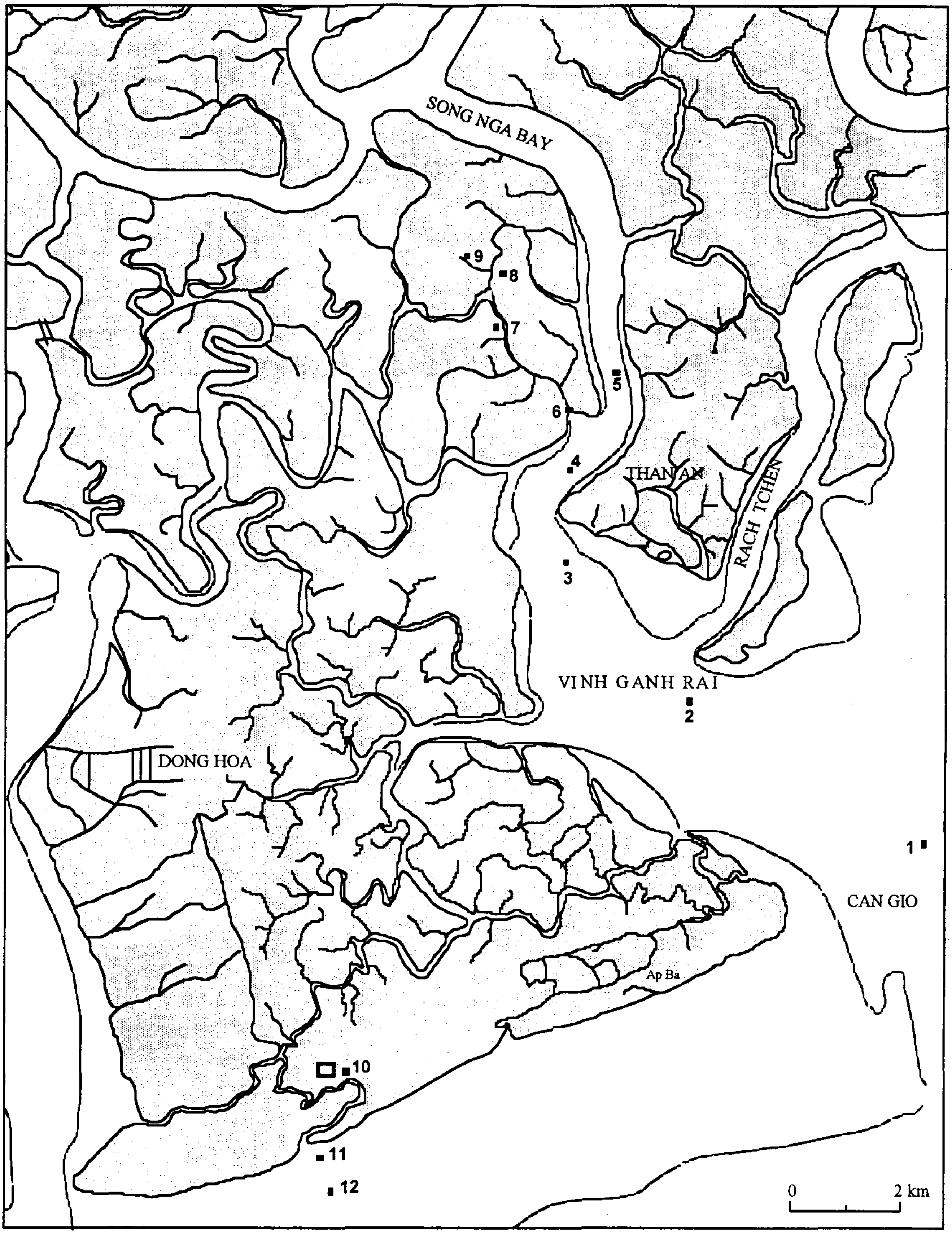


Figure 33. Location of sampling stations in Cangio estuary (Vietnam).

Hydrobiological organization

Salinity. The waters salinity presents very strong variations between the rainy season and the dry season (Mean 22 ‰ in November 1994 and 30 ‰ in May 1995). Nevertheless, in this part of the delta, waters are never fresh, even in the maximal precipitations period ; the system is under marine influence (**fig. 34**).

During the year, salinities variations in superficial waters range from 5 to 10 ‰ in the whole studied region, and are distributed according to a gradient, increasing the upper estuary in direction of the sea.

Differences of salinity between the bottom and the surface never exceed 10 ‰ whatever the season but, curiously, they invert at some points (spatially) and during the year (temporarily) (**fig. 34**). It is possible, but non demonstrated, that this phenomenon is in relationship, with a turbulent water flow in the tributary.

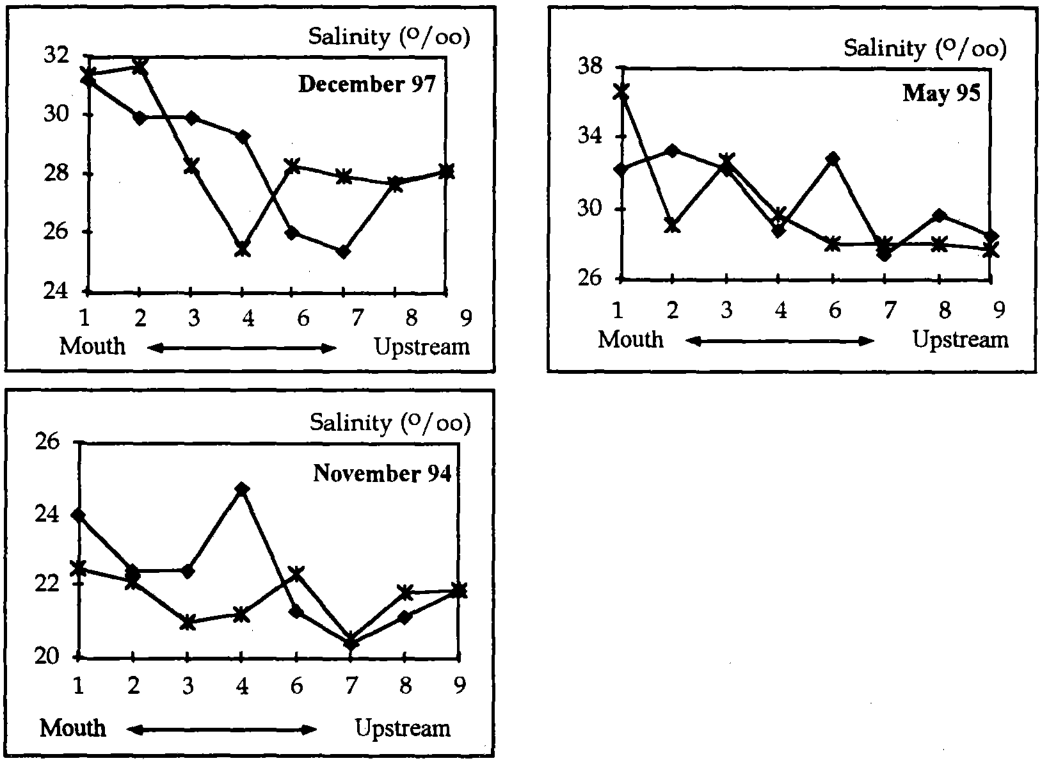


Figure 34. Repartition of salinity in Cangio estuary (Vietnam).

Suspended matter - Organic matter. During the dry season, suspended matter present a positive gradient in surface waters and a negative one in bottom waters from the sea to upstream. The difference recorded between the surface and the bottom is maximal at both extremities of the ecosystem: the mangrove zone and the outer bay where respective vertical gradients are high but inverted. This distribution is induced by a stratified hydrodynamics with a penetration of marine current, more limpid, at the bottom and the evacuation of estuarian waters at the surface.

The entrance of the estuary is characterized by a homogeneous turbidity that remains between 130 and 150 $mg.l^{-1}$ in the entire water column. In this shallow zone, currents accelerate and produce turbulences with high cinetic energy. An aquatic discontinuity is induced by the

contest between river gravity currents and tidal movements. This is called "hydrodynamic frontal transition zone".
The same phenomenon occured during the flow at the tributary mouth (station 6). This zone locally presents much turbidity and a lot of floating woody fragments.

During the ebb tide and the rainy season, these phenomena disappear, the whole ecosystem is overrun by mixed water propelled by a tidal backward and forward motion.

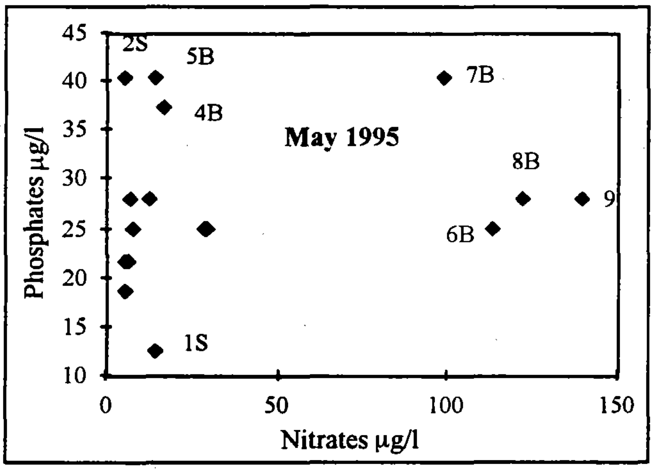
The concentration of organic matter is situated between 3 and 40 mg^{-1} with maximal values at upstream and downstream ends or again in the shallow narrow frontal zone, near station 3.

In May 1995, values of the C/N ratio gradually decrease from the bay to upstream (**fig. 35**). However, the above mentioned fronts are very clearly characterized by localized small values that interrupt the regularity of the gradient in superficial waters, at the mouth of the estuary and the distributary. Consequently, these zone with low C/N values must be colonized by bacteria. All values are inferior to 6, which indicates an intense participation of the prokaryotic compartment.

In May 1996, on the other hand, values are between 8 downstream and 17 upstream. This last value is typical in zones of mangrove (Ibrahim, 1986).

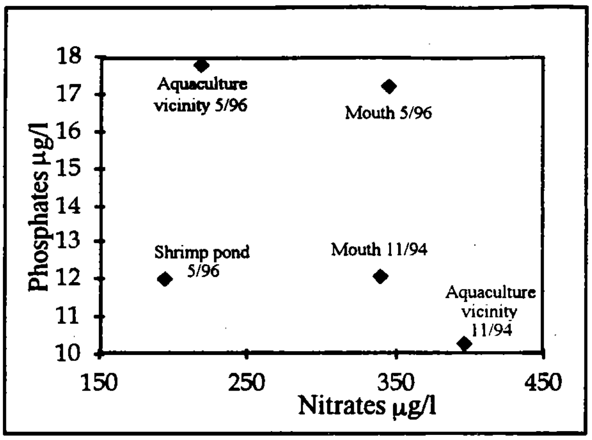
Phytoplankton

Chlorophyllian biomasses. Analysed results showed that in the dry season (12/95) the average of chlorophyllian biomass is 1.01 $^{+}$/. 0.47 mg.m^{-3} and phaeophytin 1.12 $^{+}$/. 0.60 mg.m^{-3}. In the rainy season chlorophyll and phaeophytin are respectively 5.62 $^{+}$/. 1.59 mg.m^{-3} and 2.59 $^{+}$/. 0.96 mg.m^{-3}.



Chlorophyllian biomasses are particularly significant in the affluent where nutrients are abundant. But nutrients do not have a limiting function downstream (**fig. 35**). The trophic level is relatively high and variability is high as for all the hydrological parameters.

Figure 35. Nutrients in Cangio waters (from vietnamese values).



This variability seems to be a particularity of this ecosystem. When we consider nutrients and aquaculture influence no relationship appears to exist between the enrichment of the estuary and the vicinity of aquaculture (**fig. 36**). In May 1996, near the rejects, phosphate content is high, but much higher than inside shrimp ponds. In shrimp

Figure 36. Nutrients in Cangio system (from vietnamese values).

In shrimp basins, phosphate concentrations are about 12 $mg.l^{-1}$, and near the discharge they reach only 12 $mg.l^{-1}$. Consequently nutrient contents are not completely induced by aquacultural rejects.

Ataxinomic composition. There are substantial variations in all categories of phytoplankton related to tide and space. The cell concentration of total surface phytoplankton averaged 12.10^3 $cells.ml^{-1}$ in the upstream zone and dropped to 3.10^3 $cells.ml^{-1}$ in the bay.

Counting of populations by flow cytometry showed 7 cellular eukaryotes types whatever he tide and 3 or 4 prokaryotes types according to the site and the tide.

By comparing their relative size with the same results obtained with same methodology on other sites (Lefebvre *et al.*, 1997a and b), one discovers that the two smallest populations, C1 and S3, belong to the picoplankton. Their size is inferior to 2 microns. The presence of a pigment of the phycoerythrin type in cells S3, allows to assimilate them to cyanobacteria. The picoplankton represents 14 % of the population downstream but only 2 % upstream.

During flood tide, it is possible to divide the estuary in to three zones (**fig. 37**):

- stations 1, 2 and 3 or low estuary, where the phytoplankton is dominated by C2, S1 and C6 whose densities are approximately 0.3 to $0.8.10^3$ $cells.ml^{-1}$.

- stations 4, 5 and 6 or middle estuary, where ecological conditions have changed inducing the modification of populations. Dominant types are now S4 , first with 2 to 3.10^3 cells/ml, then C6 and C2.

- finally stations 7, 8 and 9, or the affluent, where densities are stronger. Five types have a concentration superior to 10^3 cells/ml (S4, C3, C2, C6 and C4) but only S4 exceeds 2.10^3 $cells.ml^{-1}$.

During ebb tide, at station 1, C2 and S4 have practically the same density with a slight dominance of C2. At all the other stations S4 is dominant and it reaches 5.10^3 $cells.ml^{-1}$ in station 9 waters.

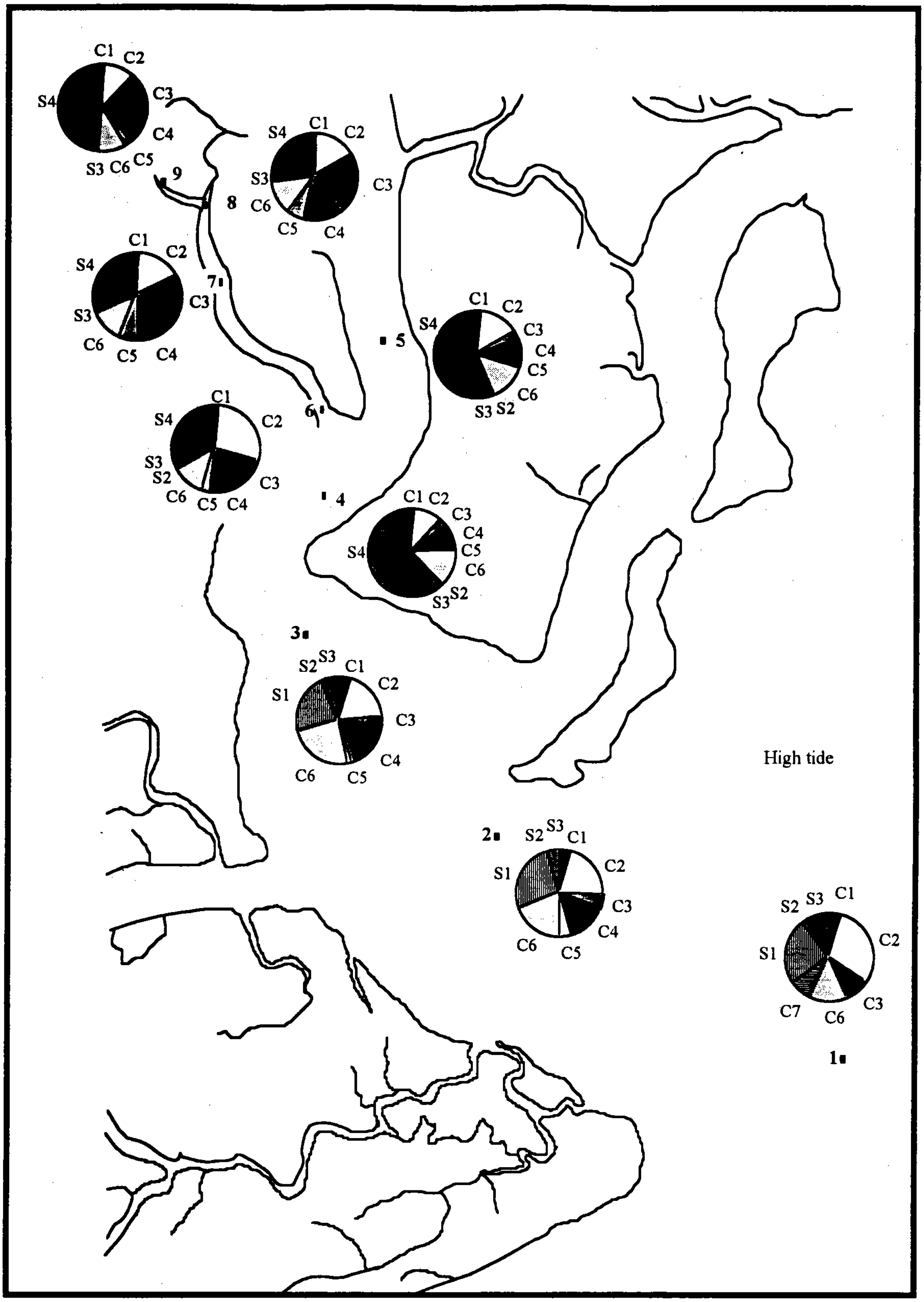
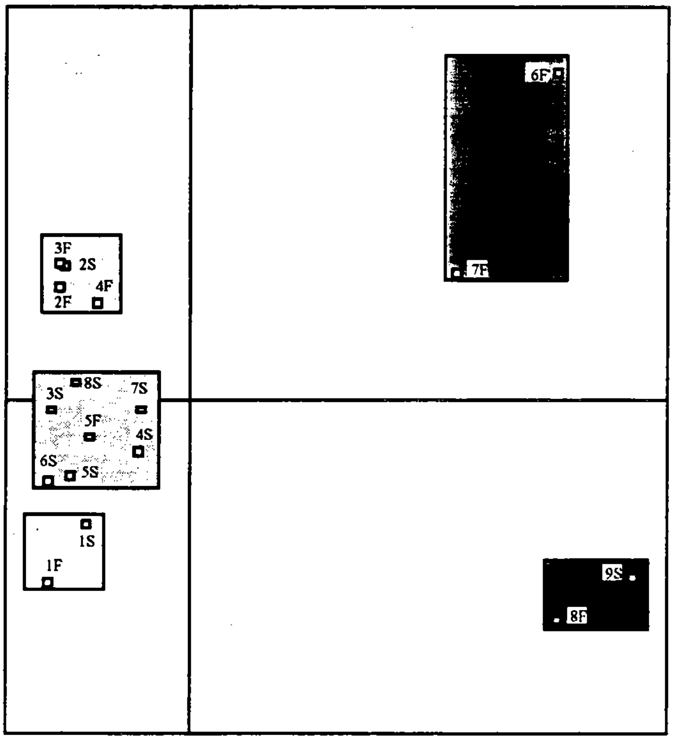


Figure 37. Composition of phytoplanktonic populations analyzed by flow cytometry in Cangio, Decem 1995, by high tide.

Main component analysis. An analysis of the main components (ACP) was undertaken. All the parameters measured in the waters (temperature, pH, conductivity, turbidity, salinity, dissolved oxygen, nitrates, nitrites, ammonia, phosphates, chlorophyll *a*, chlorophyll *b*, chlorophyll *c*, organic matter and C/N ratio) permit grouping of the stations and give a synthetic image of the estuarian ecosystem (**fig. 38**). Several groups are defined.



Descriptors : Temperature, pH, Conductivity, Turbidity, Salinity, Dissolved Oxygen dissous, Nitrites, Nitrates, Ammoniac, Phosphates, Chlorophyll a, Chlorophyll b, Chlorophyll c, matière organique, rapport C/N

Figure 38. Main component analysis with hydrobiological parameters.

- Station 1 constitutes the first group and identifies the bay where the estuary opens.

- The second group concerns the entire water column of station 2, which is the hydrodynamic frontal zone. This group remains under marine influence because of the permanent effect of the tide.

- The third group is made up of all the surface waters of the river and the tidal channel (tributary) from station 2 to station 9, the quasi totality of the superficial layer of the ecosystem. Only station 5, situated futher upstream, is affected by the entire water mass. The continental pressure is heavier there, waters of the bottom fasten to the superficial system, characterizing the lower estuary.

- The fourth group includes deep waters of the tributary, between the junction and the river, (station 6) and the mangrove zone (station 8). Indeed, the tributary is regularly flooded by enriched waters that have remained in the Rhizophora mangroves during high tide, and that flow, during ebb tide, to deep zones of the channel.

- Finally, the fifth group includes the furthest zones of mangroves that undergo less renewals of marine water. Deep zones of station 8 and station 9 situated in the Rhizophora mangrove present a high confinement induced by their terminal position in the hydrographic system studied.

Foraminifera
Sixty-three species of foraminiferas have been counted in samples of sediments harvested during the July 1995 sampling. These populations of foraminiferas are all typical of lagoonal and estuarian environments in tropical zones. The three sub-orders are well represented with, however, a dominance of hyaline species (Rotaliina). Indeed, 33 species of this type have been counted for only 16 agglutinated species and 10 porcelan species.

Specific richness. The distribution of the specific richness of the two sampled zones is organized globally in the same manner. One observes, as in all paralic systems, a marked diminution of the number of species in favour of more confined zones (Medhioub *et al.*, 1981 ; Favry *et al.*, 1996 ; Debenay *et al.*, 1993). Thus, thirty species have been counted in the bay of Vung Tau, but only ten to twenty species in the tidal channel, and, from five to ten species in the affluent situated upstream. However a slight increase in the specific richness appears in the mangrove area (station 9) where *Ammobaculites sp.* (2 species), *Ammonia parkinsoniana*, *Deuterammina sp.*, *Miliammina sp.* and *Trochammina sp.* develop more particularly.

Density. Densities are distributed according to a gradient decreasing between the bay and the farthest mangrove areas. 2000-3000 individuals for 50 cm^3 of sediment in the bay of Vung Tau, the density decreases and no more than 200 individuals are counted in the tidal channel. The density that is again 1000 individuals in 50 cm^3 of sediment in the mouth of the tributary, decreases rapidly in zones of Rhizophora mangroves where a hundred individuals subsist.

Diversity. The Fisher index of diversity (Id) (Murray, 1971) gives very significant results. Indeed, stations on the coast of Vung Tau present the strongest Id (4.5 to 5), whereas the Id decreases and varies from 1.7 to 2.2 for stations situated in the tributary.

All the populations of the deltaic region studied are dominated by *Ammonia tepida*; this ubiquist species has spread over the whole world and is reputed for its adaptation to strong variations of salinity. This species represents between 60 and 80 % of populations studied except for samples from the bay of Vung Tau (stations 11 and 12) where it accounts for only 20 to 30 % of the population.

Conclusion

In the region of Cangio, the biological zonation is managed by a horizontal component, the distance from the marine field to which are added contributions of continental waters, and a vertical component represented by the emersion time on intertidal flats. The regular emersion of intertidal zones amplifies the degree of confinement according to permanently immersed zones, situated at the same hydrodynamic distance from the sea. This hydrodynamic distance varies continually according to the amplitude of the tide and the flow of the river.

Globally, in the zone studied the continental influence of the Mekong river is responsible for the hydrobiological organization. The influence of aquaculture in the region of Cangio is masked by phenomena occuring upstream.

2.4.2.3. Tra Vinh estuary

Description. Sampling was performed at 9 stations. Station 1 was located off the mouth of the estuary (open sea) and station 9 was situated at the top of the estuary near the continental lands **(fig. 39)**.

Three additional stations were sampled for a few parameters along a radial parallel to the line of coast.

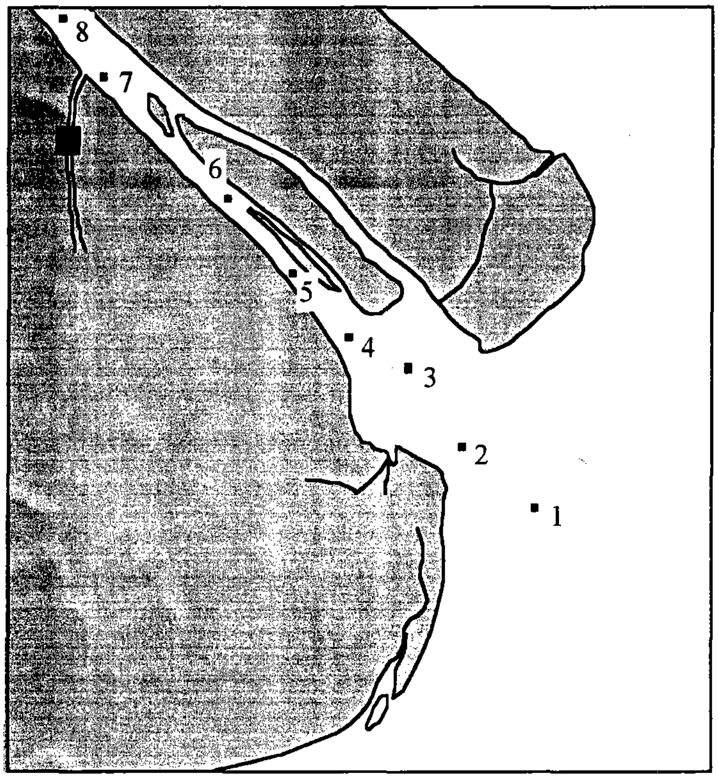


Figure 39. Location of sampling stations in Tra Vinh estuary (Vietnam).

Physico-chemical

Temperature / Salinity. The mean water column temperature recorded from the mouth to the top of the estuary varied between 30 and 32° C during May and 28 and 30° C during November.

Salinity ranged from 2 to 27 ‰ in May and 0 to 20 ‰ in November **(fig. 40)**. The limit of salt penetration varies according to the season.

Vertical profiles of both salinity and temperature showed the water column to be well mixed in the rainy season **(fig. 40)** and partially mixed during the dry season. At that time, bottom waters are colder (1 to 2° C) and slightly more salty (9 ‰ at the mouth and 3 ‰ upstream). These vertical gradients lessen when the distance from the marine domain increases. Therefore, they are induced by the marine intrusion. In the dry season, when freshwater contributions are limited to the rivers, the salinity, a conservative component, is a good indicator of the mode of circulation (Day *et al.*, 1989 ; Hayward *et al*, 1982 ; Millet and Cecchi, 1992). Salinity is not modified by biogeochemical mechanisms but only by the nature and the intensity of mixing mechanisms.

Marine waters, saltiest therefore the densest, penetrate the estuary channel by flood tide preferentially by the bottom and estuarian waters are evacuated on the surface. Tra Vinh functions according to a relatively standard circulation mode with a surface ebb and a bottom flood.

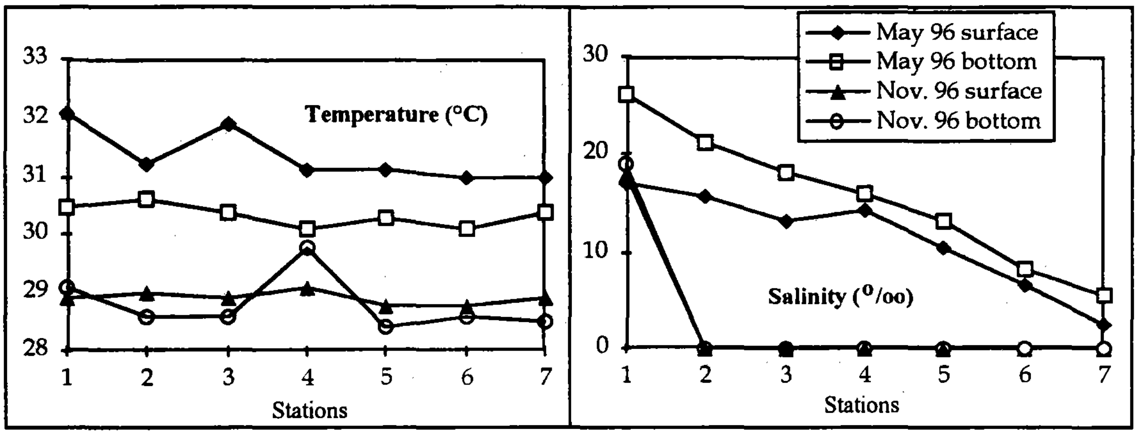


Figure 40. Spatial distribution of temperature (°C) and salinity (‰) in Tra Vinh estuary.

During the humid season, rains mask the internal organization of the ecosystem that is displaced towards downstream. The tidal river could border the seashore directly, so that fresh water leaves the river mouth without mixing with salt water and the estuarine mixing processes would actually take place within the nearshore zone (Amazon, Orenoque, Congo...) (Day *et al.*, 1989 ; Gibbs, 1970).

Globally, the temperature allows to distinguish seasonal variations and, occasionally, differences between the surface and the bottom, while the salinity describes the passage, more or less rough, from the marine field to more continental zones (**fig. 41**).

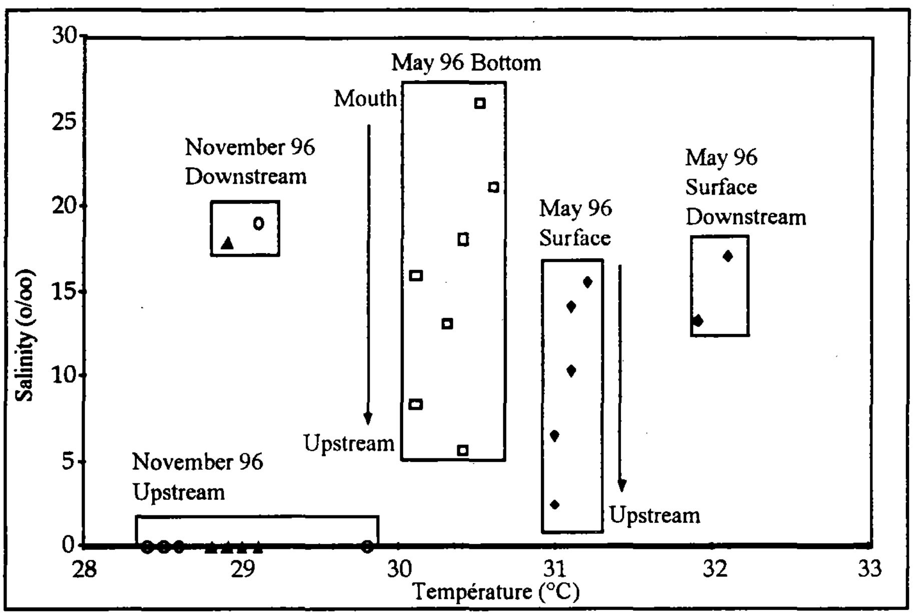


Figure 41. Salinity temperature diagram.

pH. The acidity of the waters increases slightly from the mouth toward upstream, whatever the season. Nevertheless the pH does not fall under 7 and the amplitude of variations does not exceed 1 (**fig. 42**).

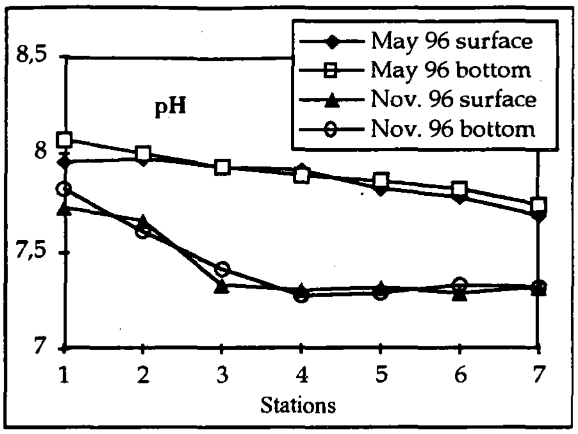


Figure 42. Spatial distribution of pH in Tra Vinh estuary.

Suspended matter - Organic matter

Gradients are inverted during the two main seasons. During the dry season suspended matters increase gradually from the sea to the upper estuary and, conversely, they decrease during the rainy season.

This gradient is about 80 $mg.l^{-1}$ but it can exceed 200 mg/l, especially in bottom waters. Indeed, the longitudinal gradient is joined by a vertical gradient that highlights a stratified hydrodynamic. The degree of mixing is not permanent. During the dry period, the column is stratified vertically by the density greater at the bottom than at the surface. During rainy episodes, a stratification breaks occur that allows particles of the bottom to be incorporated to the superficial zone.

This organization confirms the shifting of the estuarian ecosystem towards downstream. This is the case for the Amazon and many other streams in periods of spate. Then the estuarian mixing occurs in the neritic zone (Gibbs, 1970 ; Day *et al.*, 1989).

Nutrients. Analyses realized in November show that nutrient contents are highler in the estuary than at reference stations situated off the mouth (**table 37**).

Table 37. Nutrients concentrations in Tra Vinh estuary.

November 1996	NO2 mg/l	NO3 mg/l	PO4 mg/l	SiO3 mg/l	N/P mg/l
Estuary	14 7-16	369 180-1050	29 18-50	2192 1088-2938	32 14-100
Outside	7 5-10	267 240-295	28 5-47	2492 2175-2950	35 13-109

Chlorophyllian biomasses. In the central part of the Mekong delta (Travinh province), the variations of primary productivity between dry and rainy seasons are relatively small (70 mgC/m^3/day in May and 60 mgC/m^3/day in November).

Chlorophyll presents spatial variability from the mouth of the estuary to the upstream zone. During the dry season biomasses vary from 1,03 to 0,73 $mg.m^{-3}$ and during the rainy season from 0,98 to 1,02 $mg.m^{-3}$.

Carbon-Nitrogen. During the rainy season, the value of the C/N ratio decreases from the inner estuary. Whatever the season, this ratio is maximal (between 7 and 9) at the entrance of the channel, where the estuary narrows. It corresponds to the zone of the "muddy cork", where the organic detritic matter, coming from mangroves, concentrates and deposits, because of the the slowing up of the currents in this zone.

Ataxinomic composition. The ataxinomic composition of phytoplanktonic population, is marked by a flow cytometry, from stations 1 to 7 of Tra Vinh estuary (**fig. 43**). Two distinct cell types are characterized by their relative size and their apparent content in pigments. This concerns picoeucaryotes (PEUC) and cyanobacterias (CYAN).

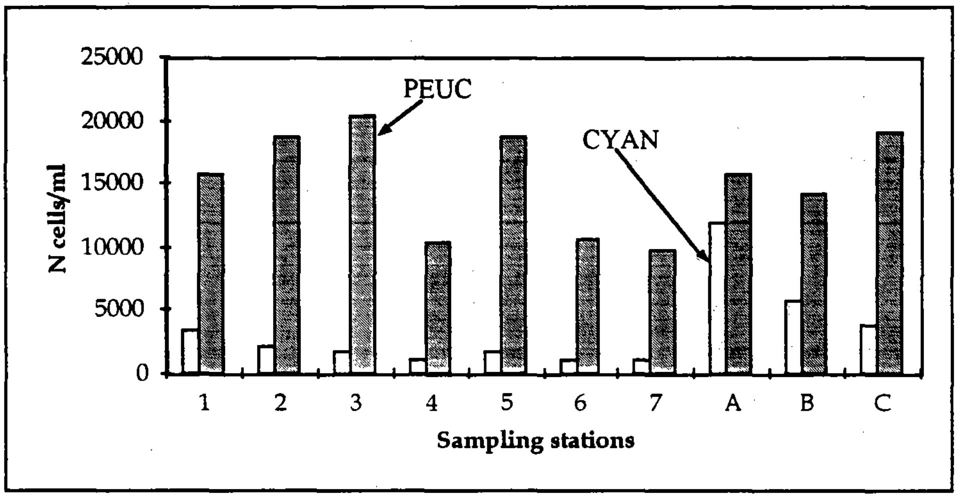
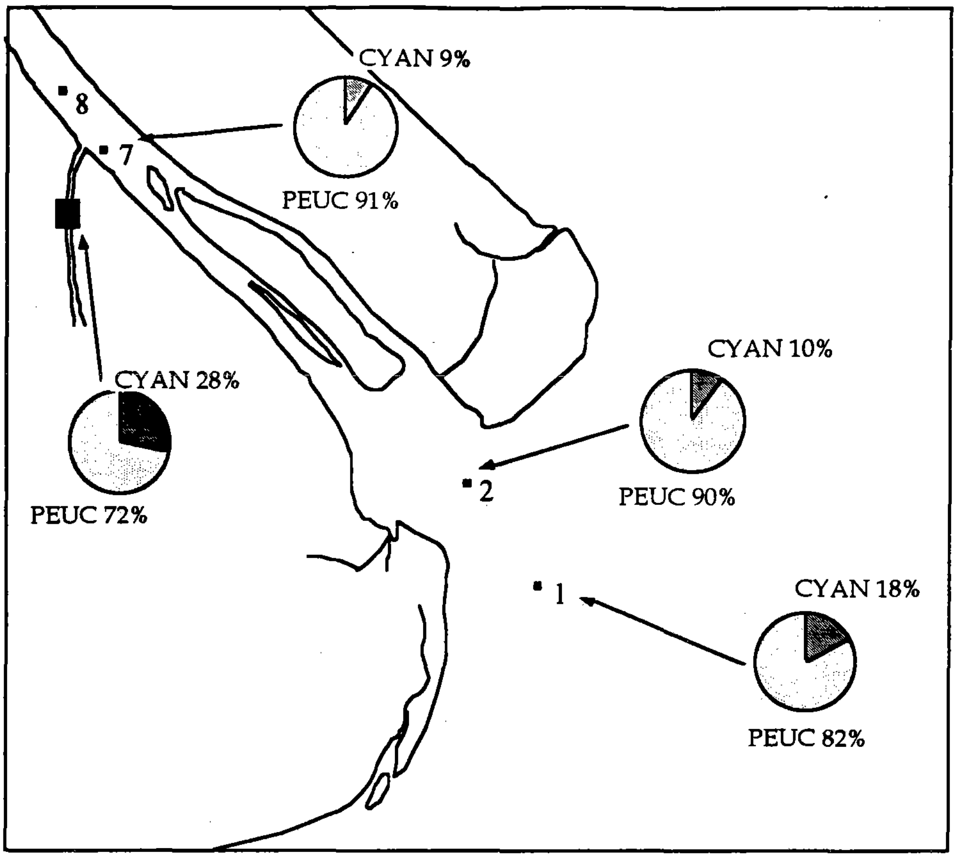


Figure 43. Phytoplanktonic population density (above) and abundance (below) in Tra Vinh estuary.



The concentration of picoeucaryotes increases regularly from station 1 to station 3, simultaneously with the distances from the sea, but at the entrance of the estuarian channel this density falls significantly. Then, in the middle estuary it oscillates between 10 and 20.10^3 cells/ml as in the other part of the estuary and in the shrimps ponds.

Cyanobacterias decrease regularly with the rate of marine water renewal ($3.4.10^3$ $cells.ml^{-1}$ to 10^3 $cells.ml^{-1}$). Nevertheless, it increases again in aquacultural basins, signifying that a procaryote cellular type adapted to this milieu exists. There would therefore be two populations of cyanobacterias in the estuary of Tra Vinh, the first of marine origin which disappears slowly and the second which is characteristic of breeding zones.

Conclusion

The Tra Vinh estuary is mainly characterized by a very high seasonal variability. Thus, in the rainy season, the paralic ecosystem is displaced offshore (in the sea) and the whole zone of the study belongs to the continental field. In the dry season, the organization of hydrobiological parameters (salinity, suspended matter...) shows the presence of a vertical stratification, induced by internal hydrodynamics and exchanges with the sea.

2.4.3. New-Caledonie ecosystems

2.4.3.1. Introduction

New Caledonia spreads over 19 000 km^2. It is situated in the south west of the Pacific Ocean, at 1500 km from the Australian coast.

It possesses an oceanic tropical climate and is submitted to marked climatical variations. Two seasons can be distinguished:

- the hot and rainy season, from November to April, with tropical perturbations (cyclones...) and temperatures ranging between 25 and 40° C.

- the "cold" season from June to September, characterized by atmospheric temperatures from 18 to 30° C and precipitations in July.

The bay of Saint Vincent (**fig. 44**) is located on the south coast of the island of New Caledonia, North-west of Noumea. It forms a complex of several bays, one of which is studied here: Nawa. The two other bays studied are located on the north of the complex: Ouano and Teremba.

Saint Vincent bay offers an example of ennoyement of the relief, which started during the post-Würmian transgression. It is strewn with rocky islets, whose small vertical cliffs show the erosion exerted by the currents.

Two missions were carried out. The first took place in February 1995, just before the implantation of an aquacultural farm in Ouano bay (**table 38**). The site was unexploited up to then. The second mission was in December 1996, after the implantation of the Ouano farm.

Table 38. Dates of sampling missions in New Caledonia.

Dates	Sites
February 1995	Ouano - Teremba - Nawa
December 1996	Ouano - Teremba - Nawa

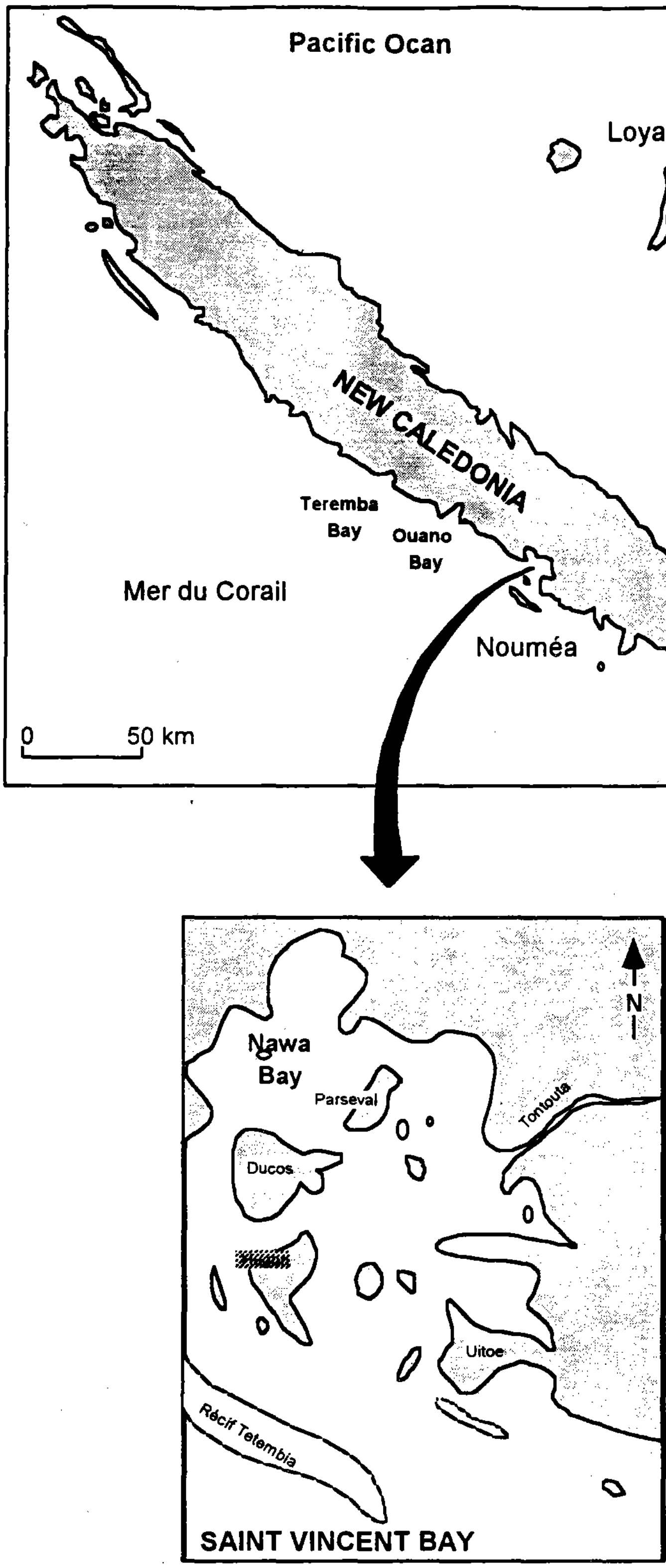


Figure 44. Location of study sites in Saint Vincent Bay (New Caledonia).

2.4.3.2. Ouano bay

Description. The bay of Ouano is widely open on the bay of Chambeyron (**fig. 45**). However this apparent opening is reduced by the coral reefs which delimit a channel with a depth of 1 to 6 meters. Those channels go along the north and south coasts of the Ras Islet. This coral islet is situated in the middle of the mouth of the basin.

Several rivers and brooks flow into the bay in a zone colonized by the mangrove.

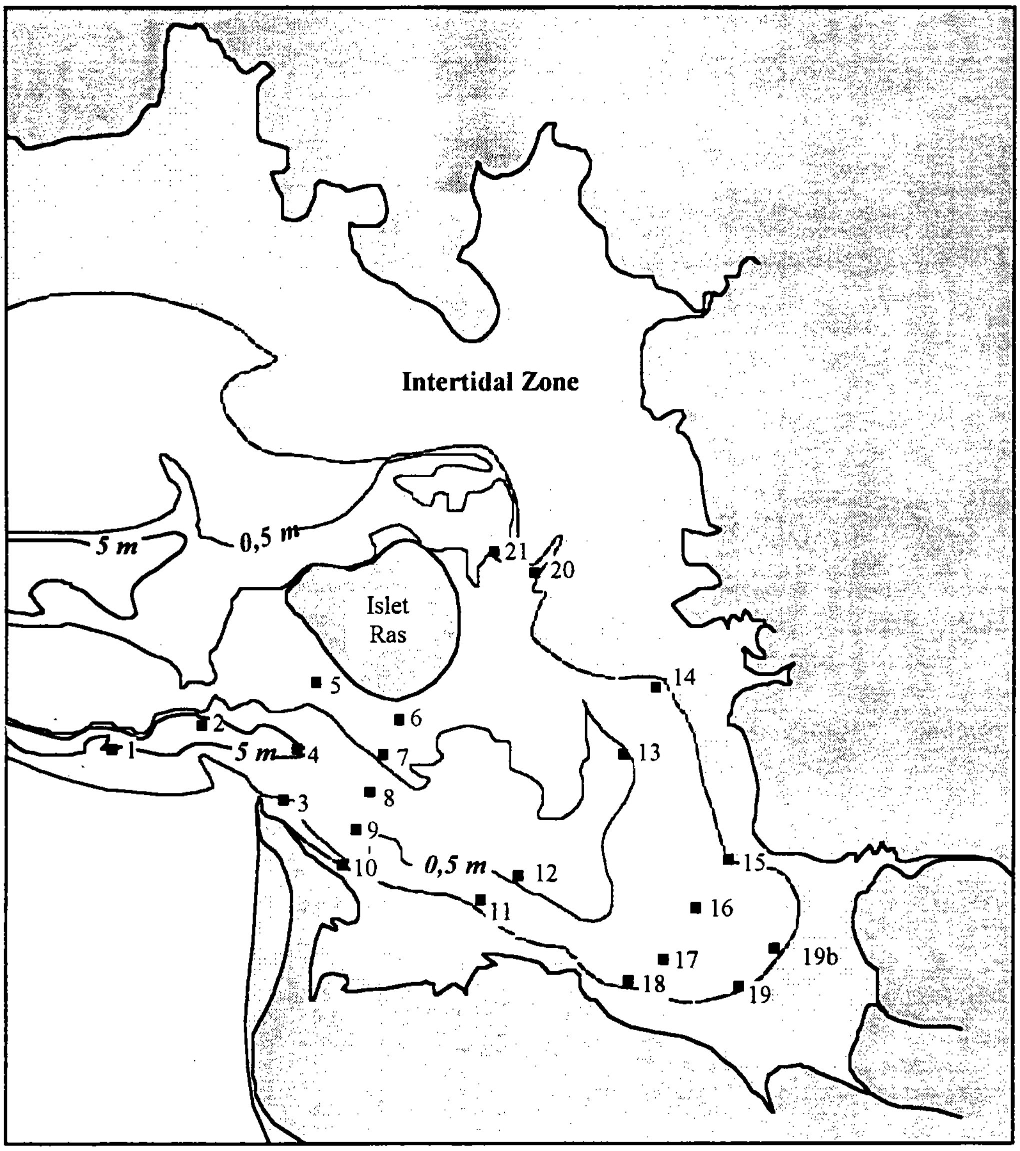


Figure 45. Location of sampling stations in Ouano Bay (New Caledonia).

Shrimp ponds are settled on the land, water exchanges between the bay and shrimp ponds are in mangrove. The pumping station is between stations 18 and 19 and the waste water is evacuated all along the coast at the bottom of the bay, in the mangrove. A possible impact of the aquaculture would first be apparent in this zone of the ecosystem.

Salinity. In February, salinities in the bay are situated between 38 and 41 ‰ in surface and 34 and 41 ‰ at the bottom. They are distributed according to a positive gradient from the mouth towards the last radial (stations 15 to 18). Beyond this radial the salinity decreases.

Contributions of fresh water have a local influence all along the mangrove zone at the farthest edge of bay.

Under simultaneous effects of the tide, that serves the basin with oceanic waters, and the evaporation that contribute to concentrate them, content in salt of oceanic waters increases slowly. This phase of evaporation is limited, in space, by contributions of fresh water from rivers, and, in time, by the rainy periods.

The repartition of salinities on the whole basin shows a levogyre hydrodynamic. Oceanic waters penetrate the bay directly by the channel (station 1-2), turn around the islet and leave out of the ecosystem in the shallower zone (station 19-20).The isolines of salinity show the water movments inside the bay.

In December, salinity is homogeneous in the whole bay, with a mean value of 40 ‰. The less salted waters are those of the deeper part of the channel.

Organic matter. In February, organic matter rates vary from 9 to 31 % but 90 % of the stations present values oscillating between 20 and 30 %.

Minimal values correspond at the bottom of the stations. In this zone, contents in suspended matter (SM) are close to the mean (8.5 $mg.l^{-1}$) and the concentration in organic matter (OM) is relatively weak (< 1.3 $mg.l^{-1}$ or 9 to 16 %). Waters that penetrate in the bay are submitted to an organic enrichment but moderate during this period of the year.

At station 19, where the organic matter rate is similar to that of the mouth one (18 %), values of SM are among the highest (12.4 $mg.l^{-1}$). The concentration in organic matter is not particularly weak (2.2 $mg.l^{-1}$, mean of the basin: 2.0 $mg.l^{-1}$) but the first phenomenon is the elevation of suspended matter. In this zone the bathymetry is weak and sediments are constituted of fine particles, winds and currents maintain the mixing of the surface sediments.

In December, concentrations in SM and OM are globally weaker (**fig. 46**). They are organized according to gradients increasing in the direction of edges and specially in the aquacultural installation zone.

The vicinity of the aquacultural farm induces values superior to 10 $mg.l^{-1}$ for SM and superior to 2 $mg.l^{-1}$ for OM. During this period 20 % of suspended matter has an organic origin.

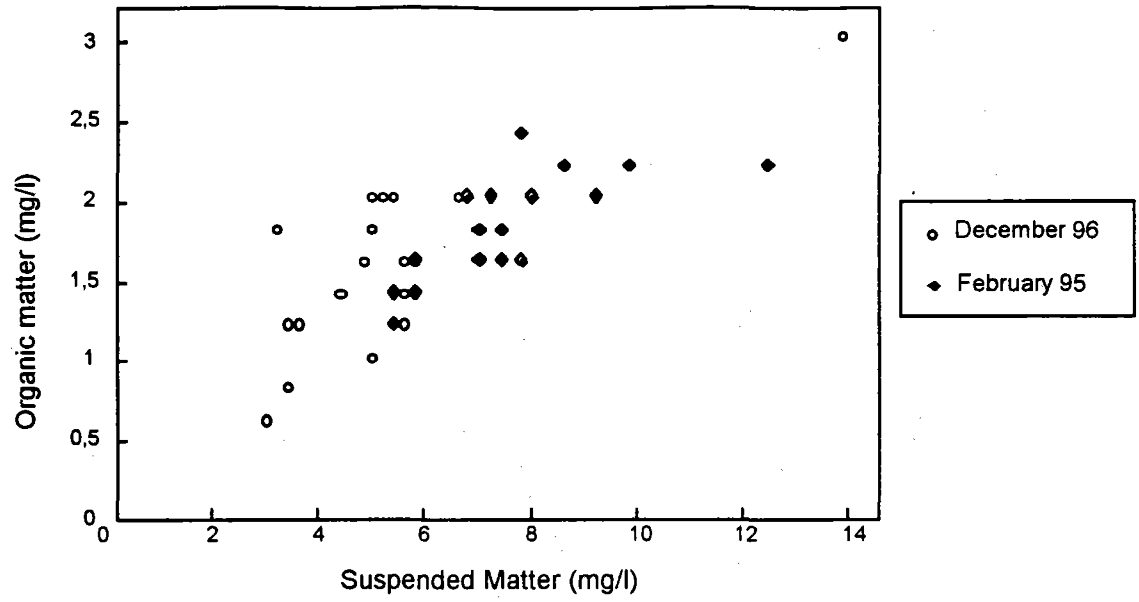


Figure 46. Evolution of suspended matter and organic matter concentrations from 1995 to 1996, in Ouano Bay (New Caledonia).

Chlorophyllian biomasses. In February, chlorophyllian biomassess are moderate. The mean is 1.1 mg.m^{-3} in surface and 1.4 mg.m^{-3} at the bottom; they exceed 2 mg.m^{-3} only in a small zone (station 12 surface and bottom and stations 8 and 9 at the bottom only). It is in this same zone that the most important modifications of hydrologic parameters and notably an increase of salinity occured. This concordance allows for the hypothesis that this zone represents a transition between a milieu under a relative oceanic influence and a strictly paralic one. This limit fluctuates in time and its location is the consequence of climatical and tidal conditions during the days before the sampling.

At the entrance of the channel the phaeophytin rates are weak (< 30 %). Phytoplanktonic populations renew rapidly although their development is limited. In the functional units most isolated from the main currents, rates of phaeophytin remain inferior to 50 %. It is only in the intertidal zone that phytoplanktonic renewal rates are insufficient and that the chlorophyll degrades more rapidly.

In December, biomasses mean chlorophyllians decrease again (0.8mg.m^{-3} in surface and 1.2 mg.m^{-3} at the bottom), rates of phaeophytin are also weaker except for the intertidal zone **(fig. 47)**.

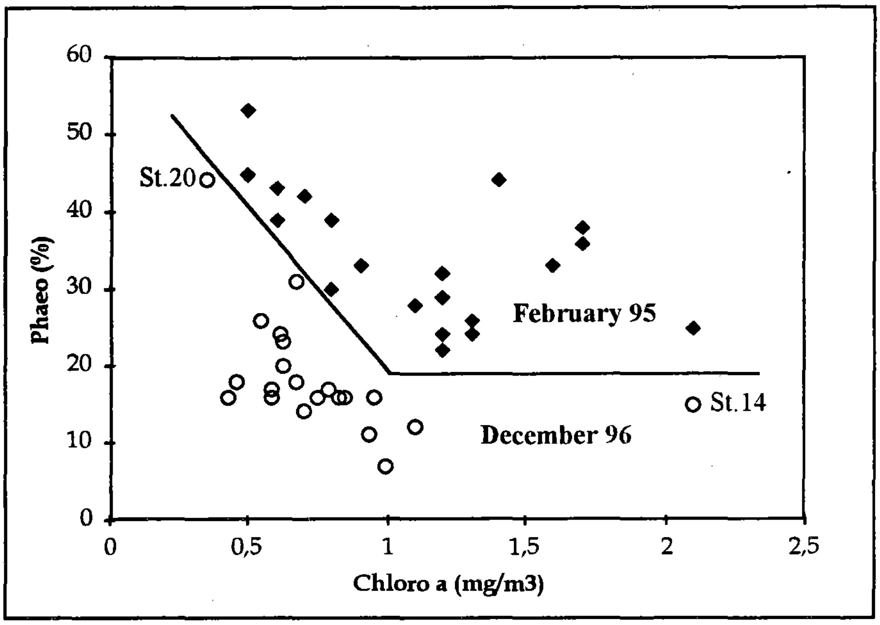


Figure 47. Evolution of chlorophyllian biomasses (mg.m^{-3}) and phaeophytin rates from 1995 to 1996, in Ouano Bay (New Caledonia).

Chlorophyllian biomassess increase simultaneously with the organic matter. They are weak at the entrance of the bay and the maxima are near aquacultural installations and along tht edge where lagoonal waters are evacuated (**fig. 48**). The influence of waste discharge from aquaculture on chlorophyllian biomassess seems limited to the zone located in the direct vicinity of the aquacultural evacuation channel.

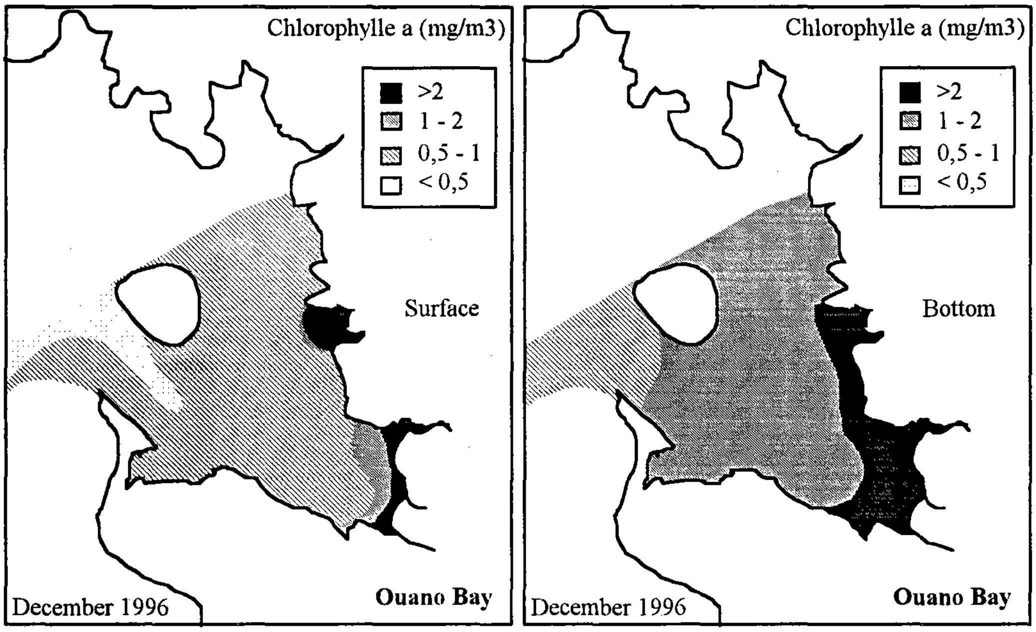


Figure 48. Repartition of chlorophyllian biomasses in Ouano Bay (New Caledonia).

Ataxinomic phytoplanktonic composition. By using criteria from previous studies (Chretiennot-Dinet *et al.*, 1995), we identified three groups of phytoplanktonic cells: eucaryotic picophytoplankton (PEUC), picocyanobacteria (CYAN) and the smallest cells with low chlorophyll and phycoerythrin (PRO) content.

Percentages of CYAN relative to total phytoplanktonic cells show that in Ouano bay the phytoplanktonic community is clearly dominated by small cyanobacteria, identified as *Synechococcus* type **(fig. 49)**.

Cyanobacteria dominate the population from station 1 to station 12. They represent 91 to 96 % of the phytoplanktonic density in surface waters. At the bottom they are slightly less abundant (73 to 91 %) in favor of PRO (6 to 23 %).

From station 17 and to the edge of the bay the PRO dominate in abundance. In integrated values, the abundance of PRO, CYAN and PEUC becomes respectively 50-60 %, 30-40 % and 10 %. Therefore, a modification of populations occurs that point to a modification of environmental conditions. Here again, as in Merak Belantung, a non identified population but whose relative size and pigment content, close to those of the smallest known organisms, dominates the phytoplanktonic population in the most confined zone of an ecosystem and in connection with aquacultural installations. This cellular type could become a bioindicator of the influence of breeding on the milieu.

Conclusion

In the Ouano bay the main current is circular, it is responsible for the renewal of the milieu in oceanic water. Nevertheless during the second mission the hydrodynamic did not seem sufficient to maintain the hydrobiological characteristics of an open ecosystem. The salinity and the organic matter had increased. Besides this temporal variability (seasonal and/or in connection with the aquacultural farm ?), a heterogeneite appears through the phytoplanktonic populations modification when the distance from the entrance of the bay increases.

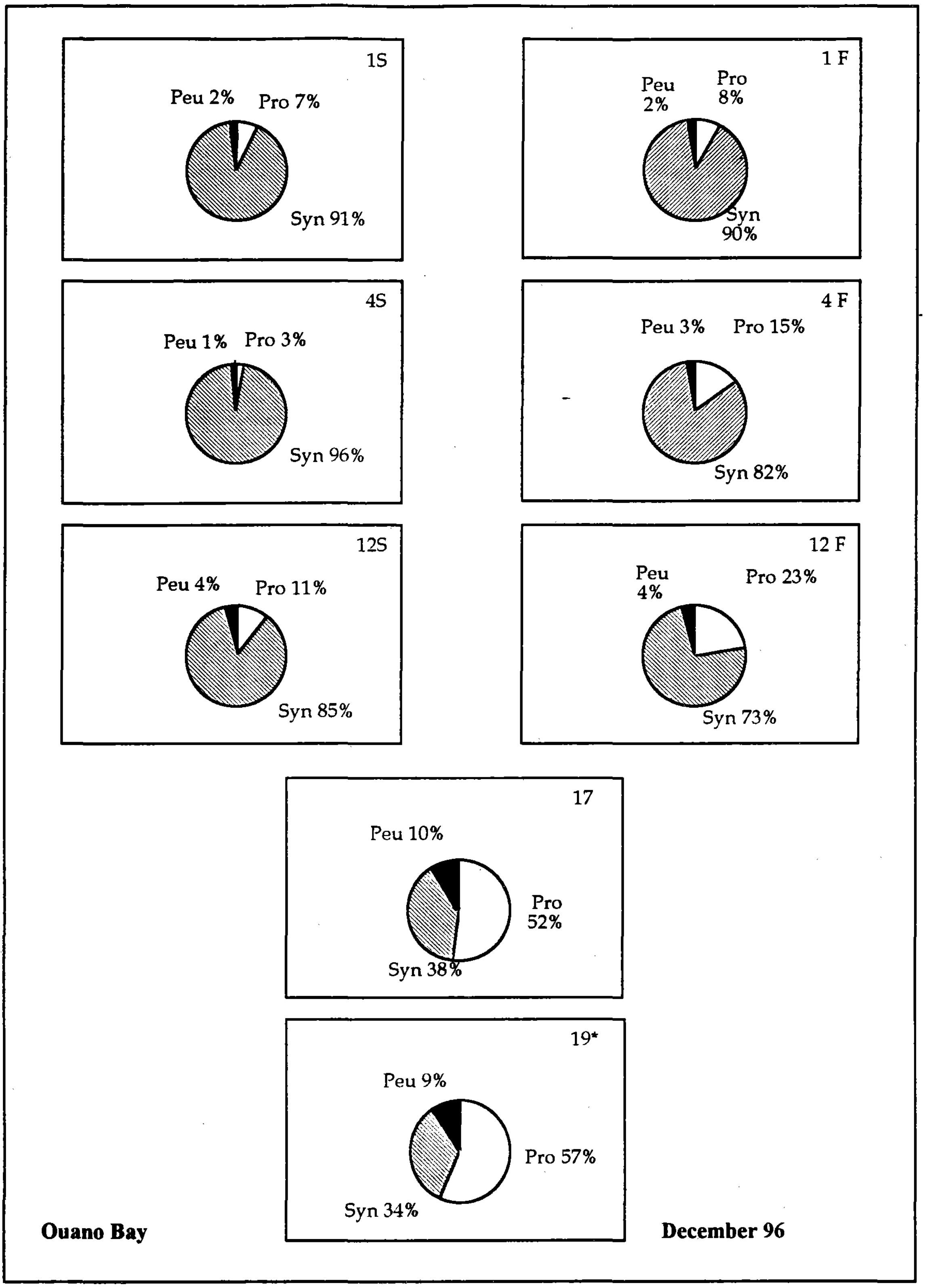


Figure 49. Ataxinomic composition of phytoplanktonic stocking, analysed by flow cytometry in Ouano bay, (New Caledonia) (anlyses by flow cytometry have been realised by J. Blanchot - ORSTOM Nouméa)

2.4.3.3. Teremba bay

Description. The Bay of Teremba is situated at about 50 kilometers to the north of the complex of St Vincent. It is possible to distinguish the bay itself and a small "lagoon" close to basins of aquaculture and separated from the whole basin by a mangroves barrier. In this small annexe 7 sampling stations have been located (**fig. 50**). The pumping station of the farm is siuated near the sampling station number 1. 10 other stations are distributed in the bay. Only surface waters are studied, because of the very weak depth.

The waste water is evacuated from the farm to another bay on the north of Teremba bay.

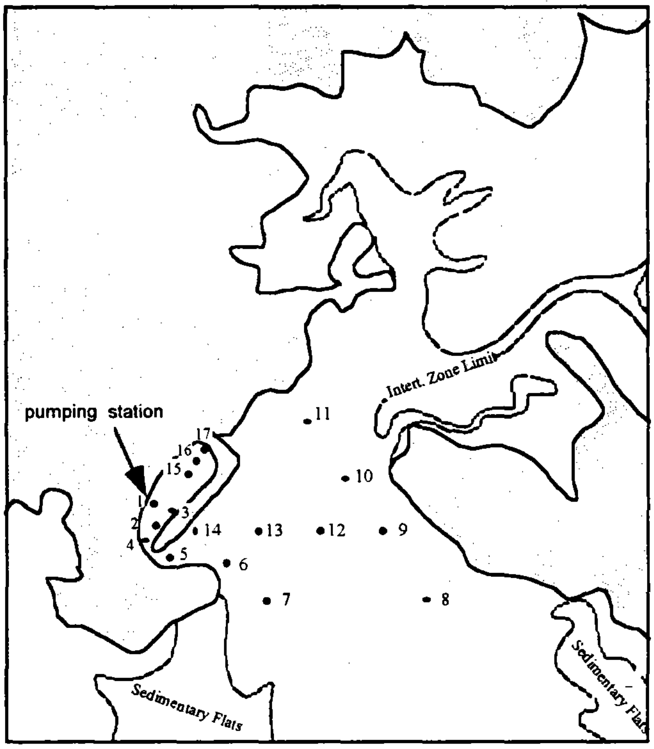


Figure 50. Location of sampling stations in Teremba bay (New Caledonia).

Temperature and salinity. In February 1995, salinities vary between 38.3 ‰ and 40 ‰. The highest salinities are recorded in the annexe. In December 1996, waters seem less salted but only a few measurements have been realized.

Temperatures vary between 28 and 30° C in February 1995 and 29° C and 30° C in December 1996. Whatever the period, the coldest waters are encountered at the entrance of the bay.

Oxygen and pH. In February 1995, concentrations in dissolved oxygen vary between 6 and 10 $mg.l^{-1}$. Weakest values are measured at stations 15, 16 and 17 at the extremity of the annexe. In December 1996, at all stations, contents in dissolved oxygen fall and are situated between 4 and 7 $mg.l^{-1}$. Whatever the date, waters of the bay are more oxygenated than those of the small lagoon.

The pH is slightly highler (mean: 8.2) in February than in December (mean: 8); but its spatial variations are too weak to be interpretable.

Chlorophyllian biomasses. In December 1996, biomasses increase with the distance from the mouth (< 1 mg.m^{-3}) firstly in direction of the extremity of the bay and secondly of the microlagoon (8.71 mg.m^{-3}) **(fig. 51)**.

In February 1995, mean biomass was weaker and the maximum, already mentioneded in the annexe, was 7.59 mg.m^{-3}.

Similarly to the increase of the chlorophyll from February to December, the content of waters in phaeophytin has varied only slighty.

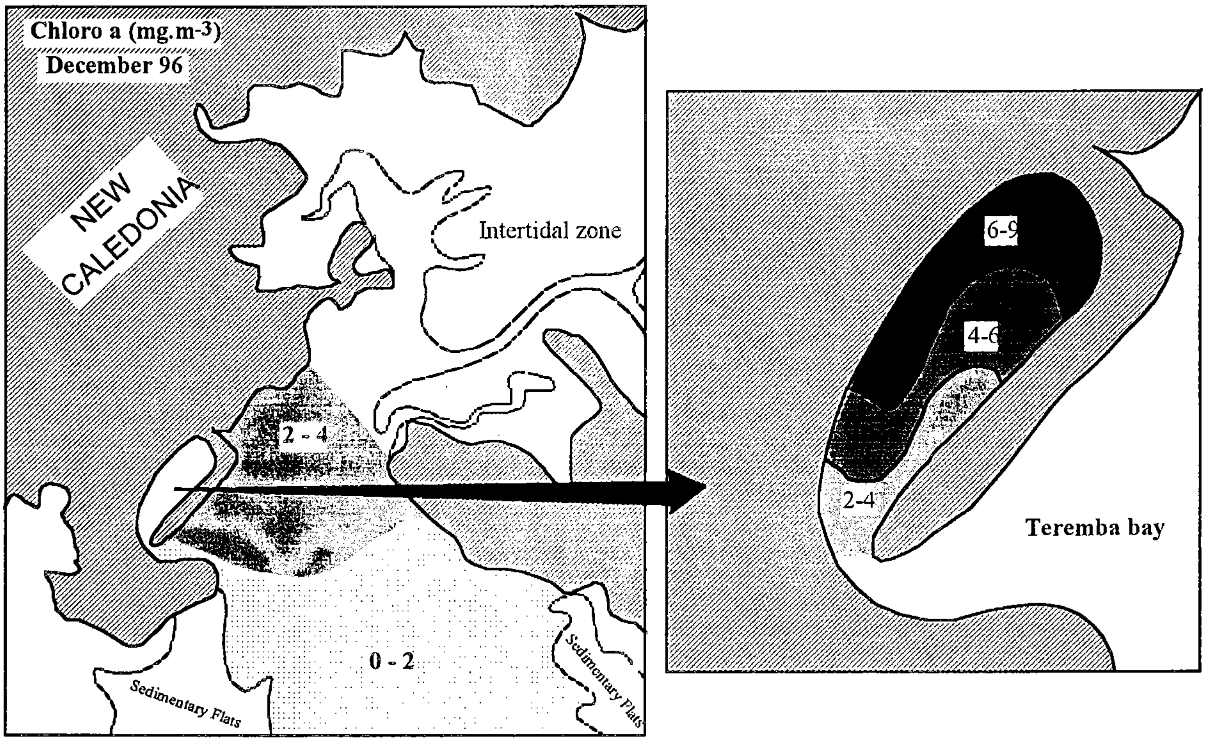


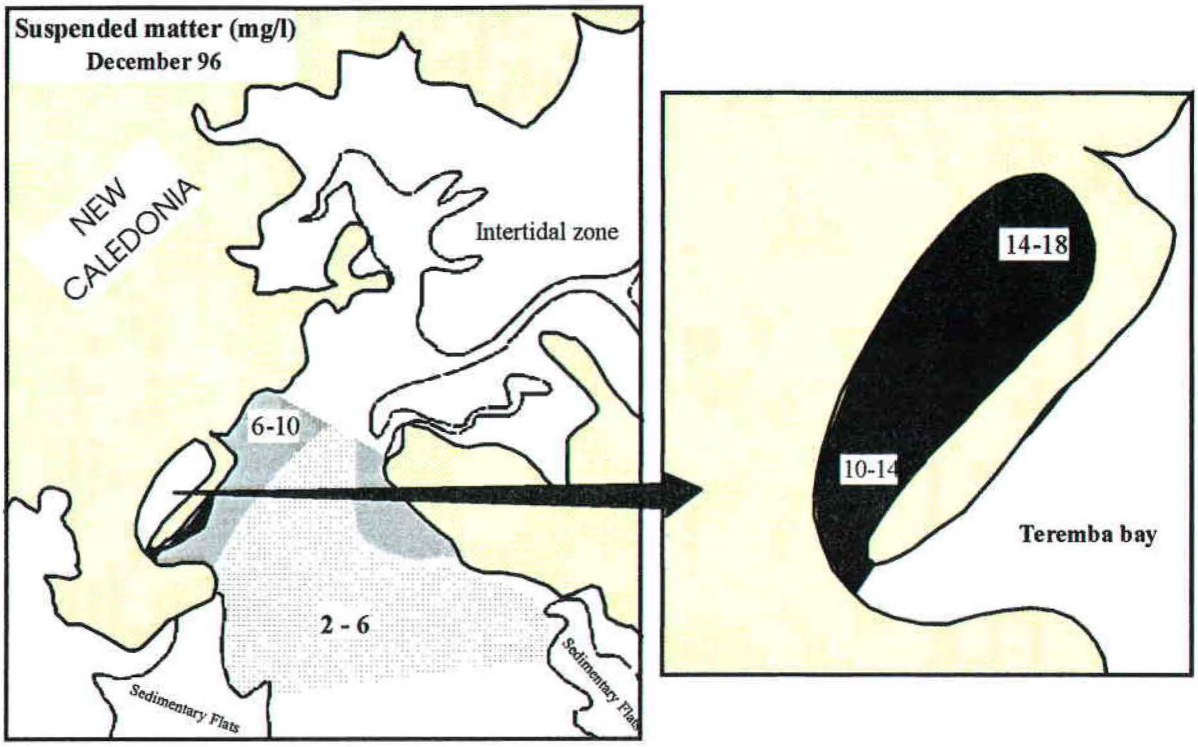
Figure 51. Spatial repartition of chlorophyllian biomasses in Teremba bay.

Organic matter. Suspended matter contents vary between 4 and 23 mg.l^{-1} **(fig. 52)**. In February 1995, contents are superior 10mg.l^{-1} in all the northern part of the bay and in the annexe lagoon. In December 1996, these same values are characteristic of the appendix **(fig. 52)**.

Results highlight a relative organic enrichment of this microlagoon. The organic matter has doubled there (from 2 to 4 mg/l) **(fig. 51)**. This zone is isolated, surrounded by mangrove.The global geomorphology of the site induces a natural confinement of this region.

The mean of the C/N ratio is 7.4 in the bay and superior to 9 in the microlagoon. This evolution is the direct consequence of the increase of organic carbon while contents in organic nitrogen remain stable.

In the core of the mangrove this ratio can reach a value of 17 The situation and more particularly the surrounding flora can explain this distribution.



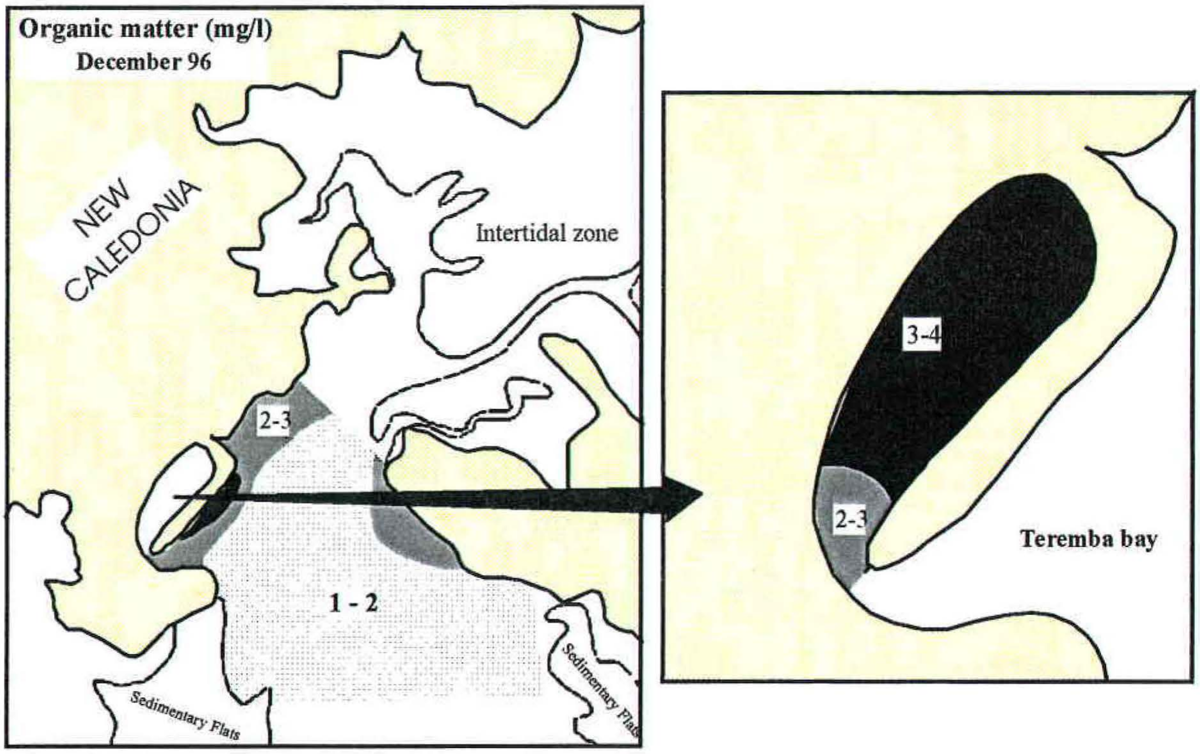


Figure 52. Spatial repartition of suspended and organic matter concentrations in Teremba bay (New Caledonia).

2.4.3.4. Nawa bay

Description. Among the different ecosystems situated near to the ocean, the bay of Nawa is at the bottom of the St Vincent complex.

Basins of aquaculture have been working for about ten years at the extremity of the bay (station 1,2). 12 stations are regularly distributed in the basin (**fig. 53**).

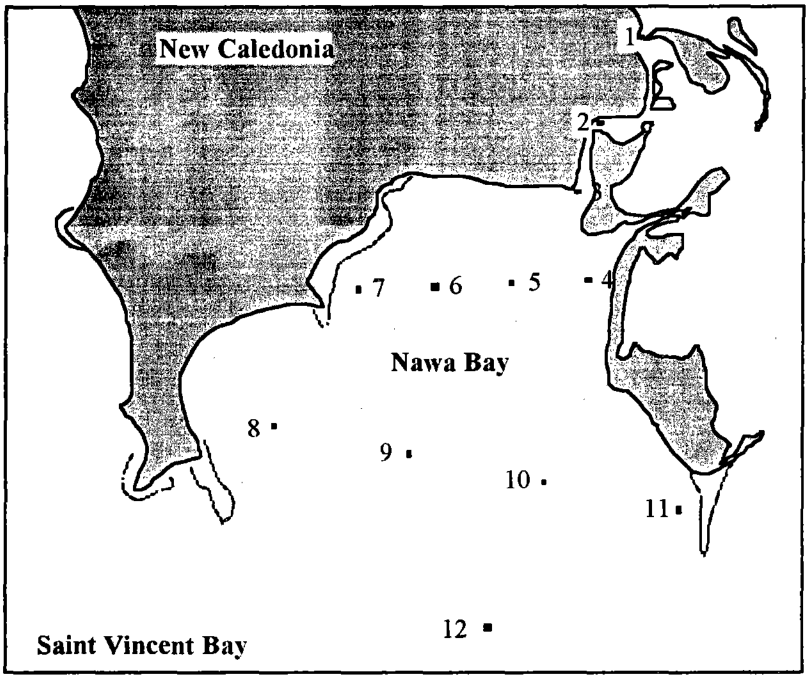


Figure 53. Location of sampling stations in Nawa Bay (New Caledonia).

Temperature and salinity. In Nawa bay, salinities vary between 36 and 40 ‰ in surface and bottom waters. They are distributed according to a gradient decreasing towards the mouth of the bay. Values are maximal (40 ‰) in the vicinity of mangroves and close to the aquacultural farm of Saint Vincent (stations 1, 2 and 3).

In February 95, temperatures vary between 28.9 and 30.8° C at the surface and at the bottom. Weakest values are recorded at stations 1 and 2.

In December 96, spatial temperature variations are more important, between 27,9 and 31° C. The gradient observed, is inverse; values are over 29,5° C from station 1 to station 6 whatever the depth, maximum is recorded at station 1 (31° C).

Globally, waters are slightly warmer at the surface that at the bottom.

Concentrations in dissolved oxygen vary, in February 1995, between 6.3 and 8.1 mg/l and in December 1996, between 4.4 and 6.9 mg/l.

In February 1995, the most turbide waters are at the extremity of the bay, in the channel bordered by mangrove and aquacultural installations.

pH varies between 8.1 and 8.5 in February 1995. Values are globally weaker in December 1996 at the 3 stations situated upstream, where they do not exceed 8.

Suspended matter - Organic matter. Concentrations in suspended matter do not exceed 20 mg.l^{-1}. In February as in December, two gradients appear. One is vertical in the column of water and grows in direction of the bottom. The other gradient is horizontal, suspended matter and the turbidity decrease towards the mouth.

In February 1995, the totality of Nawa bay waters presents a contribution of the organic matter to total suspended matter ranging from 10 to 30 % with a mean content inferior to 3 mg.l^{-1}. These values are only exceeded in the channel (stations 1, 2, and 3) and at the vicinity of its mouth where the depth is relatively important.

In December 1996, the importance of quantitative suspended matter in waters remains similar but the organic matter represents from 15 to 50 %. The distribution is the same: maximal concentrations in confined zones and a diminution when the rate of renewal in oceanic water increases (**fig. 54**).

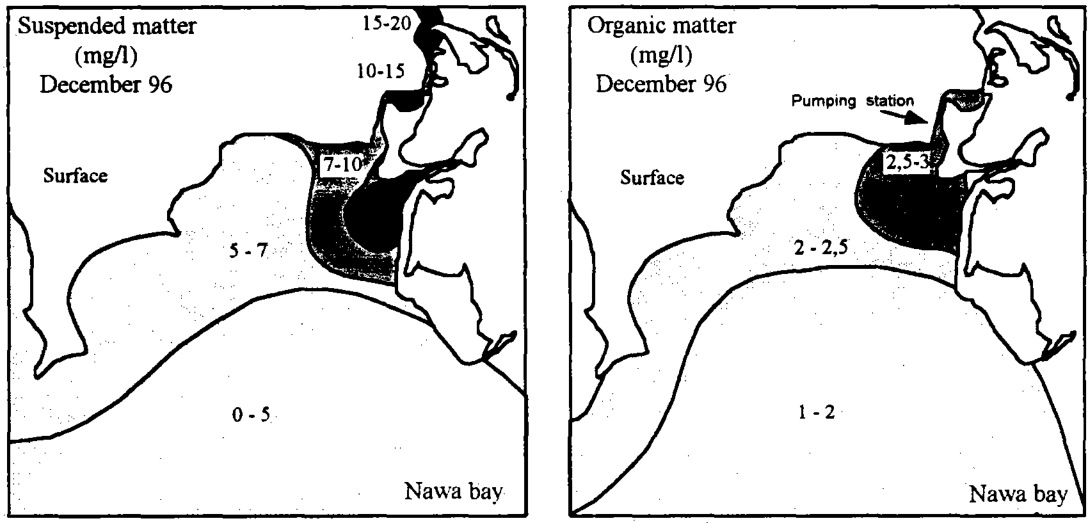
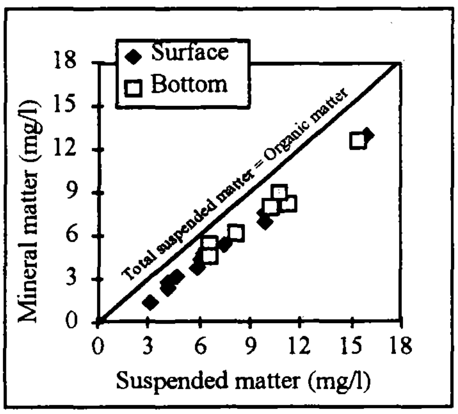


Figure 54. Repartition of suspended and organic matter in Nawa Bay.



Besides, at each station there is a good linear correlation between MM and SM. This type of relation means that in the whole basin the variations of SM are directly due to the variations of mineral matter during this period of the year.

Figure 55. Mineral matter evolution according to suspended matter variations in Nawa bay (12/1996).

Phytoplankton

Chlorophyllian biomasses. In February and December and in all the sampling stations of the basin, chlorophyllian biomasses do not exceed 4 mg.m^{-3}. Inferior to 1 mg.m^{-3} in the major part of the basin, they increased in the channel and upstream they reach 3,6 mg.m^{-3}. They are slightly higher in February 1995 than in December 1996.

Ataxinomic composition. There again, as in Ouano bay, the phytoplanktonic population is composed of picoeucaryotes (PEU) and cyanobacteria (CYAN) as well as of a smaller non identified population (PRO). The spatial evolution in density and in percentage of PEU and PRO is the same. They increase from the zone open on the ocean towards the continental margin, then in the channel (**fig. 56**). CYAN are always dominant and their cellular concentration oscillates around 84.10^3 cells/ml.

The rupture of slope of the curve at station 3 shows that the channel represents an ecosystem in communication with the bay but with particular characteristics. In the upstream zone and especially near station 1 ecological conditions seem to favor the density increase of populations less represented in most oceanic zones.

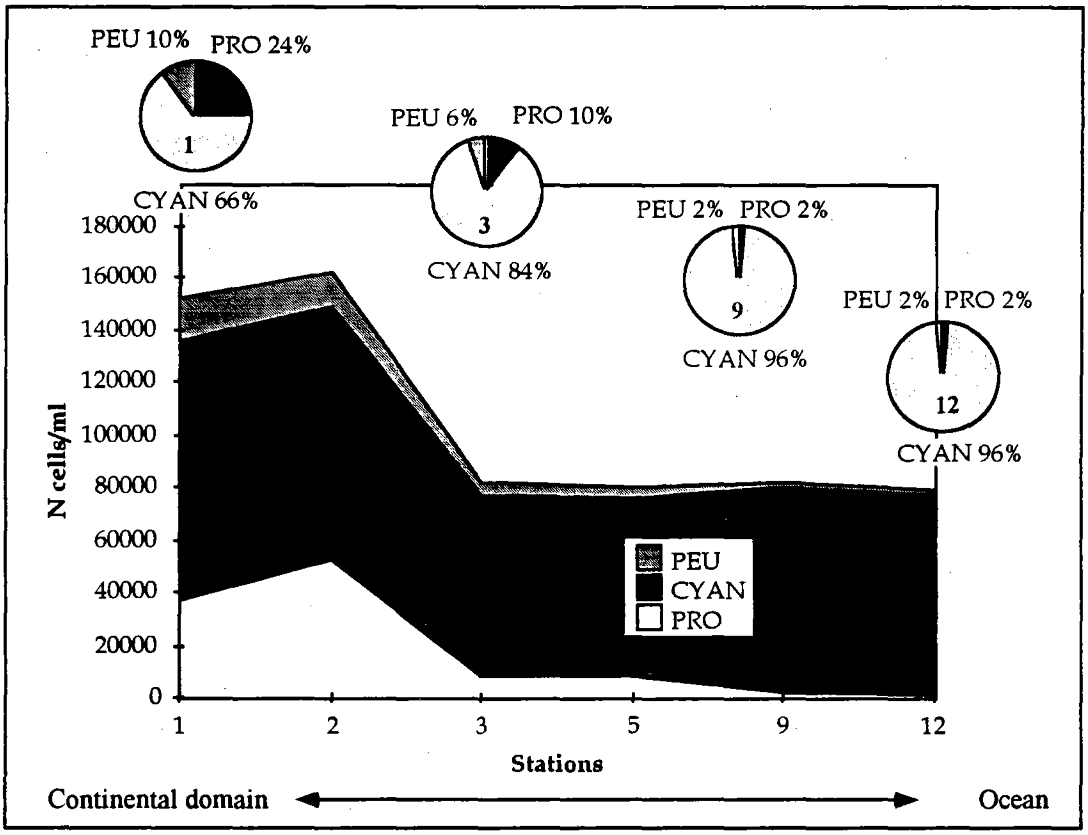


Figure 56. Repartition of phytoplanktonic populations analyzed by flow cytometry in Nawa bay - density and abundance (anlyses have been realised by J. Blanchot - ORSTOM Nouméa).

Conclusion

Despite the size of the communication with the saint Vincent complex, the whole bay of Nawa is not under oceanic influence. It presents strong horizontal gradients. In most marginal zones, isolated from the main currents, suspended matters, organic matter and chlorophyll biomasses are high. This ecosystem is composed of two zones. The first one has characteristics close to those of the coastal area, the second one is under continental contributions influence, ecological conditions notably induce the development of the phytoplanktonic population of picoeukaryotes that generally indicate confined zones (Lefebvre, 1997).

2.4.4. Conclusion on site characterization

These ecosystems have different geological origins. They are located all in Asia. Indonesian basins communicates with Java Sea (Sri Minosari), Indian Ocean (Merak Belantung), New Caledonian ones with Coral Sea and Vietnamese ones with China Sea. These are estuaries, deltaïc complexes or, more or less, open bays.

Consequently, marine and continental pressures are various in quality as in quantity.

Globally, main hydrobiological parameters allows to make a kind of classification in term of organic enrichment, or trophic level.

On **fig. 57** which groups all the ecosystems in fonction of suspended and organic matter it is possible to distinguish clearly the most marine basins: Merak Belantung (Indonesia) and Ouano (New Caledonia). Tra Vinh, and local zones of Sri Minosari (Indonesia) and Ca Mau (Vietnam) are enriched in organic matter, under continental influence.

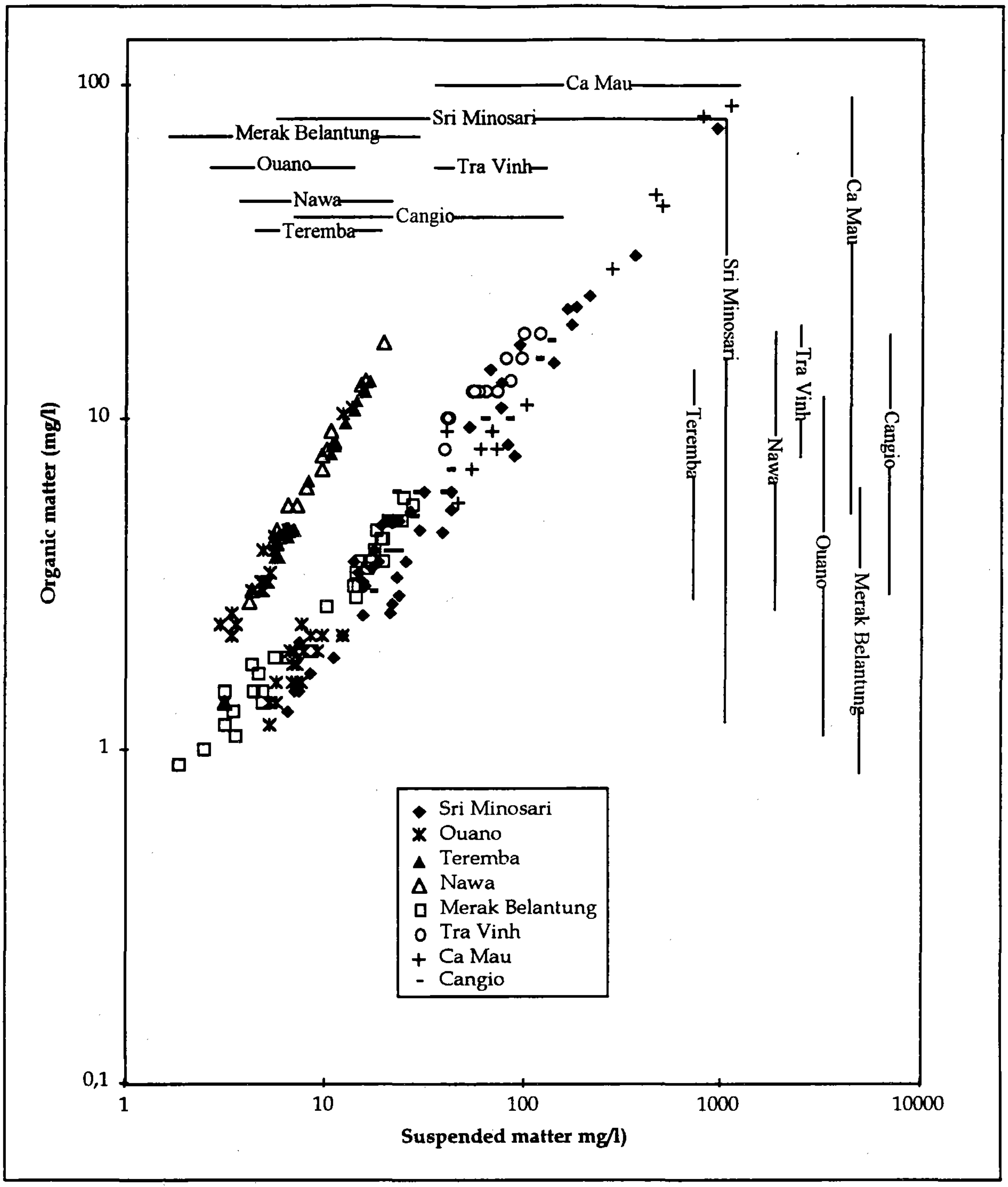


Figure 57. Situation of the different sites according to suspended and organic matter.

Degradation of chlorophyll a from phytoplanctonic cells enrichs the water in phaeophytin. The concentration in phaeophytin increases when chlorophyllian biomasses increase, it is a phenomenon of phytoplanctonic populations succession. On this graph ecosystems are distributed according to their geographical location.

In New Caledonia, chlorophyllian biomasses do not exceed 10 mg.m^{-3}, and the phaeophytin is very weak. In Cangio estuary (Vietnam) variations of phaeophytin are far stronger that those of the chlorophyll, according to the zone the conditions are more or less favorable for phytoplanktonic species maintenance. In Indonesia, the quantity of phaeophytin is slightly stronger but the two sites are very different. In Sri Minosari (Indonesia) the global trophic level is very high (the highest) and in the bay of Merak Belantung waters are closer to oligotrophy, and points representing stations are grouped in a circle, it is a more homogeneous ecosystem.

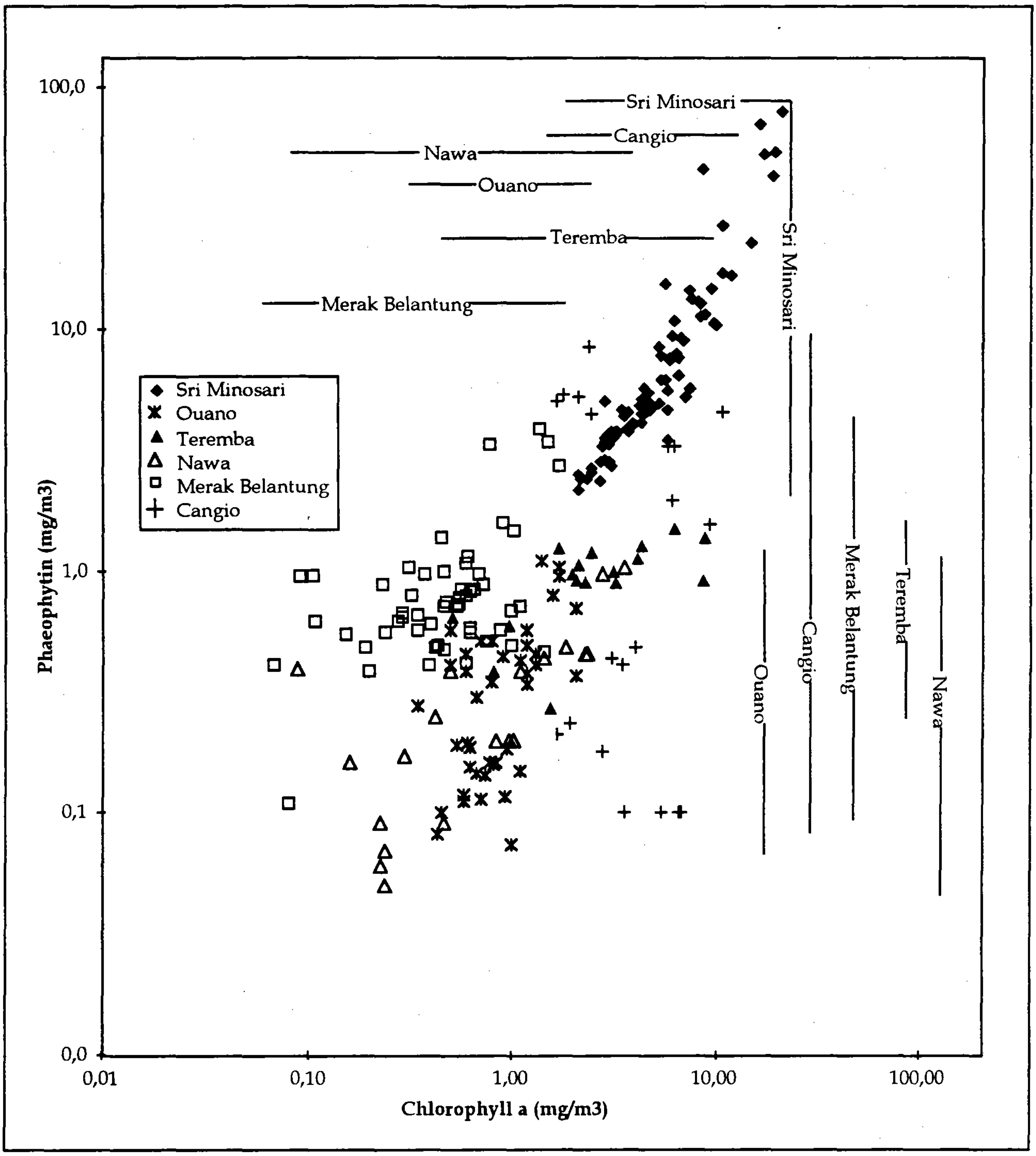


Figure 58. Situation of the different sites according to chlorophyll and phaeophytin contents.

2.5. Synthesis and conclusion

The ecosystems studied were chosen because they were highly representative of the different coastal areas encountered in South-East Asia and in the Pacific Ocean. The selected ecosystems represent a wide variety of structures in terms of hydrodynamism, variable continental influence to more marine influence, degree of aquaculture intensification and production efficiency expressed in tons.ha^{-1}. $year^{-1}$.

The summary of the research carried out on the characterization of a number of sites and follow-up of their evolution under aquacultural pressure when farming shrimp in earthen ponds leads to a classification of these ecosystems in three categories (types).

The first categorie is represented by coralline sites (Merak Belantung in Indonesia and New Caledonian sites). These ecosystems are characterized by a marked stability, in terms of salinity, and more generally in terms of ecological parameters. The results of the different field surveys carried out on these sites have shown that the concentration of suspended matter, particulate organic matter, bacteria are generally low. In these ecosystems, intensive farming with high stocking density may be promoted with a good chance of success. The production of shrimp farms is high, up to several tons.ha^{-1}.$year^{-1}$ (1730 kg/ha/crop in Merak Belantung, up to 3 tons/ha/crop in Saint Vincent sites) assuming that sites are correctly selected and farms accurately managed.

The second caregory is represented by coastline ecosystems in mangrove areas (Sri Minosari, and generally speaking in the Java Sea). The influence of continental pressure is higher than in the first category. Salinity may decrease during the rainy season. Increase in the concentration of suspended matter and particulate organic matter are observed. The nature of the organic matter may change, with an increase of organic matter of continental detritical origin. The phytoplanctonic populations present an increase in the proportion of pheopigments. An increase in the concentrations of cyanobacterias and sulfate reducing bacterias is observed. Shrimp farms in these ecosystems work with low stocking densities (generally less than 10 shrimps.m^{-2}) and the production does not exceed 1 ton^{-1} .ha^{-1} . $year^{-1}$ (515 kg/ha/crop in Labuhan Maringgai, 181 and 190 kg/ha/crop in Jahung and Pala, South Sumatra) with two crops per year. The difference between sites is highly dependant on this quality, on the density of coastal land occupation and on the efficiency and quality of farm management.

The third group of the ecosystem is represented by the deltaic system (Mekong delta). In these large and complex ecosystems, continental pressure is always dominant. Salinity fluctuates, but is always low, whatever the season. It may fall as low as 0 ‰ during the rainy season. Particulate matter (total and organic), cyanobacterias, show very high concentrations. The ecosystem is dominated by fresh water dynamics, and by organic matter from continental origin. Even if the salinity increases during some periods of the year, these ecosystems belong to the continental domain. In these ecosystems, the productivity of shrimp is very low, and does not exceed a few hundred kg^{-1}.ha^{-1}. $year^{-1}$ (100 kg/ha/year in Can Gio North ; 1000 kg/ha/year in Tra Vinh ; 116,5 kg/ha/year in Bac Lieu and Ca Mau).

During the second step, the main characteristics of each group of ecosystems expressed in terms of concentration of total suspended matter, particulate organic matter, chlorophyll, percentage of pheopigments in total pigments and sulfate reducing bacterias (in water and in sediment) are tentatively represented on a single scale illustrated (**figure 58bis**). The values represent data collected in the different ecosystems studied during the 3 year programme and more precisely the data isued by the sampling stations situated closest to, either the pumping stations, or the mouth of the inlet chenal of the farms located in each

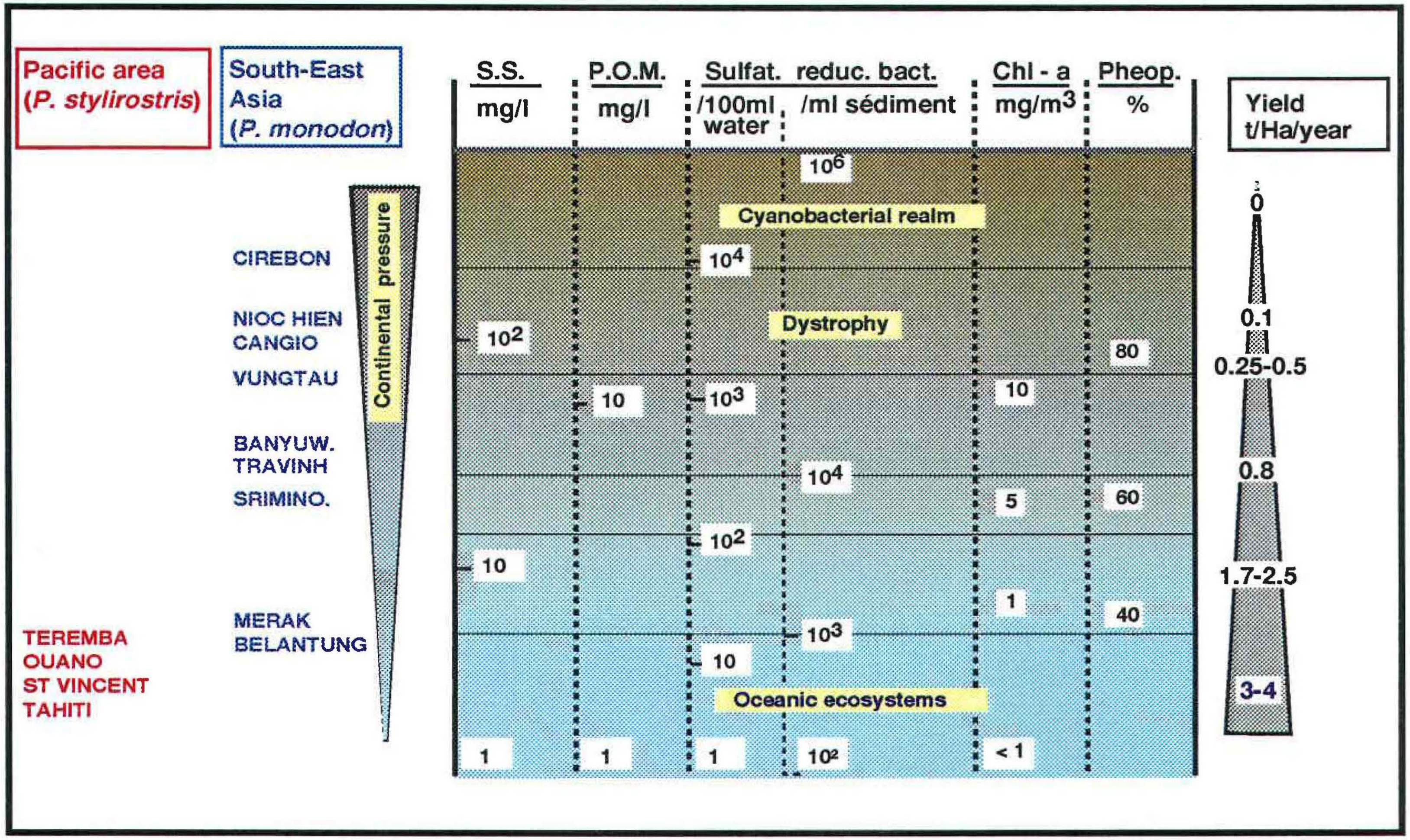


Figure 58 bis. Ecological characteristics of studied sites in South East Asia and Pacific Region in relation to shrimp production.

echosystem. The average production of the farms expressed in tons/ha/year, derived form the socio-economic part of this report, or from direct inquiries carried out at the farms, are represented on the right part of the scale. The information related to each site (left of the scale) is placed in front of their corresponding ecological characteristics. Furthermore, information on water characteristics and shrimp productivity obtained on other sites previously studied by former programmes are included.

This synthetical approach tends to demonstrate and illustrate the relationship between the productivity and the characteristics of each environment studied. The scale clearly shows that shrimp production is inverse to the concentration of the ecological parameters retained. In fact, the highest production is observed on the sites where the concentrations are the lowest in terms of concentrations of total suspended matter, particulate organic matter, chlorophyll, percentage of pheopigments in total pigments and sulfate reducing bacterias (in water and in sediment). On the contrary, on the sites where concentrations of these parameters are high shrimp production per ha is low. Also observed was the fact that these high concentrations of particulate matter (total suspended matter and organic matter) and sufato reducing bacteria could be, in a certain number of sites, directly correlated to high intensification of aquaculture in terms of surface and crops/year. This is particularly true for the site of Cirebon (North Java) where the production of the large site (>5000 ha) has decreased drastically to almost zero. In this case, the regular decrease of production has been followed and quantified with, at the same time, a significant change of environmental characteristics (increase in the concentrations of all the ecological parameters).

This indicates clearly that the scale has to be considered as a dynamic scheme.

Therefore, an environmental evolution due to the impact of waste, aquacultural or of any other type of origin (discharges from the mangrove, organic matter discharged by food industries..) will imply displacing the site to a higher level on this scale, in terms of ecological characteristics, as well as in terms of production capacity.

Certainly, the scale presented here, can only be considered as an outline of what could be a tool to predict the production capacity, in the frame of the determination of site selecting parameters, as well as a tool to predict the evolution of production as related to the evolution of the environmental characteristics, measured by a survey for example.

In addition, to define this production scale while taking into account environmental parameters, two types of shrimp were considered. *Penaeus monodon*, reared in South-east Asia, and *P. stylirostris*, reared in the Pacific Ocean.

It is not sure that the scale outlined is applicable, firstly to these two species and secondly to other species reared in earthen ponds. This scale will have to be perfected for each of the species concerned.

Moreover, this scale is defined for rearing in earthen ponds. New techniques implemented (plastic liner rearing for example) imply that the establishment and/or the "improvement" of this scale must take into account the results obtained by these new technologies which can change the relations between aquacultural activities (in terms of production) and environmental characteristics.

2.6. References

Aminot A. and Chaussepied M., 1980. Manuel des analyses chimiques en milieu marin. Centre National pour l'Exploitation des Océans, Jouve, Paris, 395 p.

Chretiennot-Dinet M.-J., Courtis C., Vaquer A., Neveux J., Claustre H., Lautier J. and Machado C., 1995. A new marine picoeucaryote: Ostreoccoccus tauri gen. et sp. nov. (Chlorophyta, Prasinophyceae). Phycologia 34: 285-292.

Day J.W., Hall C.A.S., Kemp W.M. and Yanez-Arancibia A., 1989. Estuarine ecology. John Wiley & Sons, New York, 558 p.

Debenay J.P., Perthuisot J.P. and Colleuil B., 1993. Expression numérique du confinement par les peuplements de foraminifères - Applications aux domaines paraliques actuels d'Afrique de l'ouest. C.R. Acad. Sci. Paris, t.316, série II: 1823-1830.

Favry A., Guelorget O., Debenay J.P. and Perthuisot, J.P., 1996. Répartition et organisation des foraminifères actuels dans le golfe de Kalloni (Grèce). Oceanologica Acta, 20, 2: 387-397.

Gibbs R.J., 1970. Circulation in the Amazon river estuary and adjacent Atlantic Ocean. J. Mar. Res., 28: 113-123.

Guelorget O., Martin J.L., Lefebvre A., Courtis C., Perthuisot J.P., Supangat A., Fuchs J. and Suastika M., 1995. Open sea paralic ecosystems south of Java sea - Environmental approach by flow cytometry. Journal of Coastal Research, 12, 1: 52-58.

Hayward D., Welch C.S. and Haas L.W., 1982. York-River destratification: an estuary-subestuary interaction. Science, 216: 1413-1414.

Hedges J.L. and Stern J.H., 1984. Carbon and nitrogen determinations of carbonate-containing solids. Limnol. Oceanogr., 29: 657-663.

Ibrahim A., 1986. Contribution à l'étude biogéologique de bassins paraliques égyptiens. Thèse de Doctorat d'Etat, Nantes, 252 p..

Lefebvre A., 1997. Contribution à l'étude de la diversité biogéologique du domaine paralique - Organisation et fonctionnement de quelques écosystèmes littoraux originaux. Thèse de Doctorat, Montpellier, 252 p..

Lefebvre A., Guelorget O., Perthuisot J.P. and Dafir J., 1997a. Evolution biogéologique de la lagune de Nador (Maroc) au cours de la période 1982-1993. Oceanologica Acta, 20, 2: 371-395.

Lefebvre A., Guelorget O., Perthuisot J.P., Courtis C. and Millet B., 1997b. Hydrological organization of a bahira type paralic basin - Kalloni bay (Lesbos- Greece). Ocanologica Acta, 20, 5: 757-768.

Medhioub K., Levy A. and Perthuisot J.P., 1981. Sédimentologie et micropaléontologie de la lagune d'El Biban (Sud-Est tunisien). Cahiers Micropal., 3: 101-106.

Millet B. and Cecchi P., 1992. Wind-induced hydrodynamic control of the phytoplankton biomass in a lagoon ecosystem non linear and optimal relationships. Limnol. Oceanogr., 37, 1: 140-146.

Murray J.W., 1991. Ecology and paleoecology of benthic foraminifera. Longman scientific and technical, Harlow, 397 p..

Phinney D.A. and Cucci T.L., 1989. Flow cytometry and phytoplankton. Cytometry, 10, 511-521.

Platt T., 1989. Flow cytometry in oceanography. Cytometry, 10, 500.

Trousselier M., Courties C. and Vaquer A.,1993. Recent applications of flow cytometry in aquatic microbial ecology. Biol. Cell, 78, 111 - 121.

Vaulot D., Courties C. and Partensky F., 1989. A simple method to preserve oceanic phytoplankton for cytometric analyses. Cytometry, 10, 629-635.

Yentsch C.M. and Horan P.K., 1989. Cytometry in the aquatic sciences Cytometry, 10, 497-499.

Task 3. Technical and economic survey of farm management and socio-economic analysis of common resources management in Indonesia (South Sumatra) and Vietnam (Mekong delta)

Authors: *D. Bailly* *Ensar - Rennes*
P. Raux *Ensar - Rennes*

In collaboration with
ION scientists: *Dr Nguyen Tac An and al*
BADC scientist: *Mrs. W. Malistyani and Arief Prihaningrum*

3.1. Introduction

The two studied areas of the STD3 programme, i.e. Lampung province in Indonesia and Mekong river delta in Vietnam, are both leading regions for shrimp farming in each country. The choice of the regional level for an economic study raises the question of the scope for a public policy to promote and sustain the development of this primary production. Shrimp production is well known around the world for both its high potential to generate wealth but also the high level of uncertainty attached to its capacity to be a long lasting process. After less than ten years of a significant level of development, shrimp production in both countries shows evidence of non sustainability. Spreading of diseases and increase of pond collapses are the first signs in Lampung province of a process that has already led to the complete abandon of shrimp ponds in other places in Indonesia and many other countries. In Vietnam, all attempts to intensify the production have failed and existing production is threaten. Given this context, two economic approaches can be developed to discuss the long term viability of shrimp production and the needs for public, state or user group based action.

The first, and most commonly applied approach, considers that the outcome of an industry at the regional level (or national) is the sum of each individual enterprise performance applying more or less successfully various technical process for a similar production, i.e. products to go on the same market. Public action is provided independently of individual choices and it is the responsibility of the enterprise to ensure the conditions of its success given the level of services and legal constraints provided by public authorities (transport infrastructures, labour or sanitary regulation, distribution of energy, taxation rules, ...). The enterprise has to deal with other enterprises or individuals on markets (inputs, outputs, labour, money) and following the evolution of competition it is more or less successful in applying in a profitable way organisational choices (technical, marketing, financial, human resources management). In such perspective, the difficulty to ensure long lasting benefits flows in shrimp farming can be summarised by a list of technical variables like pond management to which the mortality of shrimps and efficiency in transforming inputs into commercial size shrimp can be correlated. External costs as those incurred by pollution on the environment are not considered and viability is understood as a low profile sustainability in which profitability is the main criteria. Technical and over private organisational choices are the key to maintain profitability and there is no social or public concern about an activity to be stopped when it doesn't make any more profit. This is as long as a rather good mobility of factor is ensured, i.e. that the benefit realised and the labour can be easily employed in other ventures.

In this perspective and given the importance of water management, feed quality, PL quality, pond structure and pond management it is clear that there is a large scope for a technico-economic study to characterise the diversity of farming practices and discriminate among them those with the highest expectancy of positive economic return. Such a study would request a detailed analytical frame of farming practices and methodology to measure them in a pond/farm follow up system over a minimum of one cycle. Using a large sample of ponds managed in different ways and applying cost and benefit analysis would provide some information of the efficiency differential among rearing techniques. In this approach, the term technique would refer to different strategies such as pond design, feeding, density and stocking age of PL, water supply, water and waste disposal in a very analytical way. Although the interest of this approach cannot be denied, it has not been retained for the present study. The first reason is that the general scope of the research has been placed at the coastal ecosystem level and not the pond ecosystem level. To be feasible such an economic study would also necessitate that all biological, ecological and technical competencies would have to be focused at the analytical understanding and measurement of the functioning of pond ecosystem. Although the ground for such a survey have been largely developed in the recent years, they almost did not exist when the project was designed. Furthermore, the fact that no farming technology has really been proved to bear much less risk in the long term puts the analytical technico-economic comparative approach in a weak position. The fact that the age of the pond seems to play a discriminating role in viability of shrimp production, indicates also that such a study would have to be conducted over many cycle and then make it a very expensive research with dubious outcome.

Rather than the shrimp pond, the focus of the STD study has been the identification of a coastal ecosystem constraint, expressed in term of carrying capacity, over the potential for shrimp farming development. This alternative approach is more centred on the contribution of economic analysis to public policy. Thus the economic research looks at the various levels of decision to question the domain of collective action. Is there something that a local group of farmers, a village, a group of villages, a prefecture or a government can do to improve sustainability of shrimp farming given the problems its development encounters? But this is without forgetting that the farm, as the private level decision, is a key component of the economic development of shrimp farming. Technical choices for example are basically a private decision but that they also may be oriented by public policy (incentives, training, extension). The private returns on investment are a key incentive to a dynamic of production development or crisis. But other aspects come to mind when speaking of public policy design that are of importance both for the private management and in terms of public concern. Water management is of course and among the first an area for collective and public action. Overall quality of water is the environmental dimension of it. Distribution of water among the farms relates more to the technical dimension of farming but placed of the level of collective choices. Discharge to the environment not only create self-pollution problems among farmers but may also affect other users of coastal resources. Some nature assets like the mangroves may be positively valued against the tendency to simply destroy them to build shrimp ponds. Purchase of supply and marketing of products might be also an arena for producers co-operation or public intervention. The production of disease free and environment friendly products may receive also a strong attention from the consumers. The fact that those whose invest their money and labour force in shrimp culture have almost no alternative if this industry collapses or the irreversibility involved in turning agriculture land into shrimp ponds may also raise public concern. Those are few examples of public policy issues that relate either to industrial organisation, local/regional land planning, economic development policy, environmental policy, public health. This approach, focused at collective and public action, needs that an economic research be conducted which is different from the previous one. It is first less analytical in terms of analysing the links between production strategies and economic performances. Secondly it give importance to the industry organisation, to the public policy-making environment and to the perception and implementation of collective action toward environmental or social issues.

On the lines of this alternative approach as specific methodology has been designed requiring access to specific material. A complete methodological frame has been set first and then applied more or less partially to the two case-studies in the limits of the allocated to the economic component of this multidisciplinary project.

3.2. Methodology, material and methods

The concern of this economic research has been to identify key issues among those that would relate to the enhancement of shrimp farming sustainability in terms of the economic incentives for its development and the need for collective action. A specific framework has been designed for the analysis based on a previous research conducted in central Java under the AADCP programme. The main lines of methodology and material are described here. Results are presented in the third section. The material and results of each case-study are presented in a more detailed form in the economic reports published separately (see chapter 4 - list of publications).

The methodology applied is common to both case-studies and combines different levels of observation and analysis. Each level is analysed in the perspective of specific economic issues. The first level is the industrial organisation. The objective is to identify and characterise the main groups of economic agents contributing to the production and distribution of shrimps at a large geographical scale that can be regional or national, including the supply of inputs. The market links among these economic agents are described by good/money flows and the global output is the total production of shrimp in terms of the main type of products and marketing channels. Such description is referred as market chain analysis as it looks at how each component of the shrimp industry is supplied by or supplies another group. It also shows the dependency toward outside market for inputs or outputs. Beyond the quantification of flows and, eventually, the identification of bottlenecks in supplies, another aim is to describe the diversity of organisational structure for good or service production. As in any group analysis, the criteria for group discrimination can be numerous and there is a large part of subjectivity in their definition. The objective is to show the diversity in farm management structure independently of technical aspects but including the geographical dimension in terms of coastal ecosystem diversity. The main sources of information for this are bibliographic review, synthesis of existing global statistics and interviews to evaluate the size of the industry and describe the links among the individual agents. The group analysis (typology) of farms is based on a general quick survey to be conducted on a large number of farms. This survey is focused at the main strategic items of farm management. This has been applied in the case of Lampung province. The questionnaire is appended to this section.

The second point to be discussed is a comparative cost-benefit analysis of alternative production systems. Rather than an analytical approach of rearing techniques, as presented in the introduction, the definition of production systems refers here to the broad characteristics that might relate, hypothetically, to significant differences in cost-benefit structure of producing similar products. The starting point to discriminate the main technical option applied by the farm is either based on direct observation and interviews or on the results of the group analysis where it has been done. The case of shrimp farming is rather simple as very few criteria are enough to discriminate among farms. In fact, it appears that the stocking density is the major criteria to be used as the main differences are in terms of level of intensification. At the highest level of intensification, the type of pond defines four main techniques that appeared to be closely correlated to the location. As the variable "stocking density" and "location" play an important role in the farm typology, the cost-benefit analysis applied to the group as defined above directly provides the information needed for such comparative analysis. The cost-benefit analysis at the farm level answers the question of the incentive to private or public investors to develop the industry and some indication of differential among technical systems in terms of profitability or uncertainty. It also provides some information to evaluate the distributional impact of the different types of farming system. The distributional impact looks at the local distribution of wealth in terms of wages, investor returns and returns to other factors. This approach doesn't provide the necessary elements neither to improve the management of the production process or to evaluate the external (environmental) costs of shrimp production. A detailed economic survey of farm is the only way to collect the necessary information for this part of the work. This has been done on 99 farms in Lampung province and on 89 farms in the Mekong delta. Farms have been selected randomly with a sampling strategy based on the group analysis. This mainly uses the two criteria of level of intensification and location. The first criteria is of less importance in the Vietnamese case as the intensification is very low in all places, most of the semi and intensive project being stopped. These surveys, called Detailed Farm Surveys, have been conducted in 1996 in Indonesia and in 1997 in Vietnam. The two questionnaires, adapted to the specifities of each country, are appended to this section. This is the English versions that have been translated in the national languages.

The last question discussed is the scope and conditions for collective action. This remains at a very qualitative level looking both at the perception of collective problems by the farms and the potential or limits offered by the existing institutional conditions. Institutional conditions are the administrative organisation, the level of producer organisation, the decision-making processes to design rule and the conditions for the implementation of rules. Sources of information are bibliography and interviews within the administrative, trade or political organisations. The opportunity of both general and detailed surveys are used to gather opinion of farmers on these issues and on the perspectives of the industry. The results of this last point are presented here. The institutional analysis being very qualitative, the reader should refer to the French reports mentioned above as the space allocated to this section was insufficient to fully present the results.

The questionnaires of the surveys are appended to this "material and methods" section to serve as a methodological reference. They are:

- the 1 page General Farm Survey conducted on 1 000 farms in Lampung Province,
- the Detailed Farm Survey conducted on 99 farms in Lampung Province,
- the Detailed Farm Survey conducted on 89 farms in the Mekong River delta.

GENERAL FARM SURVEY

Identification number ❑
Village:
Farmer's name:

Tambak operation starting year: 19 ❑
Sources of income: tambak only (1) / tambak and other (2) ❑

Permanent labour (equivalent full time)
number of family member ❑
number of wage labour ❑

Land tenure:
owned land (ha) ❑
rented land (ha) ❑
other (ha) ❑

Operation of the last two crops

Technique	Crop 2			Crop 1		
applied	total area (ha)	stocking density (individual/ha)	production (kg/ha)	total area (ha)	stocking density (individual/ha)	production (kg/ha)
Traditional						
Traditional +						
Semi-intensive						
Intensive						

Number of ponds used for crop 2 ❑
Number of ponds collapsed in crop 2 (production less than 50% of expected) ❑
Number of ponds used for crop 1 ❑
Number of ponds collapsed in crop 1 (production less than 50% of expected) ❑

Nursery of shrimp PL to produce fingerlings:
area (ha) ❑ stocking size PL ❑ selling size (g) ❑ selling price ❑

Credit: Bank ❑ Middleman ❑ Feed company ❑
Selling size pieces per kg ❑
Selling price Rp/kg ❑

Will you try to increase stocking density in the future: yes (1) / no (2) / no answer (0) ❑

Opinion about the future of shrimp farming in your area:
very good ❑ good ❑ uncertain ❑ difficult ❑ very bad ❑ no opinion ❑

QUESTIONNAIRE

(detailed farm survey conducted in Lampung Province)

REMINDER FOR INTRODUCTION

- Survey on tambak farm socio-economics
- EC-ASEAN project on coastal management to support harmonious development and avoid negative consequences of intensification.
- Chosen by random selection (lotery)
- Data will be kept confidential

Village code: VI [ ]

(Tanggul Tlare: 11, Bulak Baru: 12, Panggung: 13
Clering: 21, Tunggul Sari: 31, Margo Mulyo: 32,
Langgen Harjo: 33)

Interview code: IN [ ]

(Wiwik: 1, Hisyam: 2, Busman: 3)

Farm code: "Zone" + "order number" FA [ ]

1 5 [105]

I. GENERAL

1.1. Introduction

Age 11 A [ ]
Education 11 B [ ]
1. Primary school
2. Secondary school
3. High school
4. Above

Number of people in household 11 C [ ]

1.2. Sources of income of the household

- Pond 12 A [ ]
- Paddy 12 B [ ]
- Sugar cane/tapioca 12 C [ ]
- Vegetable/fruit 12 D [ ]
- Fishing 12 E [ ]
- Administration/government officer 12 F [ ]
- Wage woker 12 G [ ]
- Pension 12 H [ ]
- Other 12 I [ ]

Is tambak the main source of income of the household: Yes / No 12 J [ ]

1.3. Tambak unit organization

1. Run only under the control of the house hold 13 A [ ]
2. Joint operation
3. External ownership
4. Other
5. No answer

In the case of joint operation
What is the share of respondent: .... % 13 B [ ]

Contribution by respondent
- Land 13 C [ ]
- Other investment 13 D [ ]
- Operational cost 13 E [ ]

Number of crops 13 F [ ]

1.4. Land

	Number of					
Item	Private (Ha)	Community (Ha)	Contract (Ha)			
- Tambak	14 A	14 B	14 C	[ ]	[ ]	[ ]
- Paddy	14 D	14 E	14 F	[ ]	[ ]	[ ]
- Other	14 G	14 H	14 I	[ ]	[ ]	[ ]

1.5. Labour (1 crop)

Relatives labour (number of people):
- wife 15 A [ ]
- children 15 B [ ]
- other 15 C [ ]

Permanent wage labour(number of people) 15 D [ ]

Seasonal wage labour
Pond preparation : Number people 15 E [ ]
Days/man 15 F [ ]

Harvest : Number people 15 G [ ]
Days/man 15 H [ ]

Other : Number people 15 I [ ]
Days/man 15 J [ ]

Permanent labour origin village 1/other place 2 15 K [ ]
(No labour permanent code 0)
Seasonal labour village 1/other place 2/none 0 15 L [ ]

II. BACKGROUND OF TAMBAK

2.1. Knowhow about tambak, origin of experience

- From parent/family 21 A [ ]
- From training 21 B [ ]
- Self experience 21 C [ ]
- With support 21 D [ ]
- Intam Package 21 E [ ]
- Other 22 F [ ]

2.2. Origin of owned land

- Inhereted from parents (ha) 22 A [ ]
- Purchased land (ha) 22 B [ ]

2.3. History of tambak operation

- Starting year of traditional (if very old: 99) 23 A [ ]
- Starting year of semi intensive 23 B [ ]
- Starting year of Intensive 23 C [ ]

2.4. Record of shrimp production

	1992		1993		1994	
Item	crop 1	crop 2	crop 1	crop 2	crop 1	crop 2
Stocking density fry/ha						
Production kg/ha						
	24A [ ] 24B [ ]	24C [ ] 24D [ ]	24E [ ] 24F [ ]	24G [ ] 24H [ ]	24I [ ] 24J [ ]	24K [ ] 24L [ ]

2.5. Record of milkfish production

	1992		1993		1994	
Item	crop 1	crop 2	crop 1	crop 2	crop 1	crop 2
Stocking density fry/ha						
Production kg/ha						
	25A [ ] 25B [ ]	24C [ ] 24D [ ]	25E [ ] 25F [ ]	25G [ ] 25H [ ]	25I [ ] 25J [ ]	25K [ ] 25L [ ]

III. POND MANAGEMENT (1994)

3.1. Growing technique

Item	Area (Ha)	
- Traditional		31A [ ]
- Semi Intensive		31B [ ]
- Intensive		31C [ ]

3.2. Growing technical description

Traditional

		Month Crop 1	Month Crop 2		
Stocking time:	Shrimp	....	....	32A [ ]	32B [ ]
	Fish	....	....	32C [ ]	32D [ ]
Harvesting periode:	Shrimp	....	....	32E [ ]	32F [ ]
	Fish	....	....	32G [ ]	32H [ ]

Semi-Intensive/Intensive

	Month Crop 1	Month Crop 2		
Stocking time: Shrimp	....	....	32I [ ]	32J [ ]
Harvesting periode: Shrimp	....	....	32K [ ]	32L [ ]

3.3. Shrimp fry supply (1993)

- Local hatchery : .... % 33A [ ]
- Outside hatchery : .... % 33B [ ]
- Wild : .... % 33C [ ]

Distance of main supply hatchery: .... hours 33D [ ]
(in decimal coding: 1 hour 30 code 1,5)

3.4. Main reason for selection/change in shrimp fry supply source

- Quality 34A [ ]
- Price 34B [ ]
- Availability (shortage) 34C [ ]
- Other 34D [ ]

IV. ECONOMICS OF FARM: Investment

4.1. Equipment (all value x 1000)

Sluice	Number	Unit price (Rp)	Expected time of use (crop)	Total Value	Depreciation
- Wood - Bamboo - Beton - PVC - Other					
Total	[ ]			[ ]	[ ]
	41A			41B	41C

Building	Number	Unit price (Rp)	Expected time of use (crop)	Total Value	Depreciation
	[ ]			[ ]	[ ]
	41D			41E	41F

Pump	Number	Unit price (Rp)	Expected time of use (crop)	Total Value	Depreciation
- Centrifuge - Sub mercible - Other					
Total	[ ]			[ ]	[ ]
	41G			41H	41I

Paddle wheel	Number	Unit price (Rp)	Expected time of use (crop)	Total Value	Depreciation
	[ ]			[ ]	[ ]
	41J			41K	41L

Genset	Number	Unit price (Rp)	Expected time of use (crop)	Total Value	Depreciation
	[ ]			[ ]	[ ]
	41M			41N	41O

Vehicle	Number	Unit price (Rp)	Expected time of use (crop)	Total Value	Depreciation
- Motor cycle - Car - Pick up - Other					
Total	[ ]			[ ]	[ ]
	41P			41Q	41R

Other Investment:
- Type
- Total value 41 S [ ]
- Time of use 41 T [ ]

4.2. Land

Land purchase:
- Total value 42A [ ]
- Year of purchase 42B [ ]
- Price Rp1000/ha 42C [ ]

Pond construction:
Cost per ha 42D [ ]

V. FARM ECONONOMICS: OPERATIONAL COST

5.1. Supply of fry

Item	Size/Fry	Stocking density	Price
PL	51A	51B	51C
Fish	51D	51E	51F

[ ] [ ] [ ]
[ ] [ ] [ ]

5.2. Feed

Type: natural/artificial feed

Item	Cost	
Fertilizer:		
- Organic		52 A [ ]
- Unorganic		52 B [ ]

Item	Quantity (T)	Cost		
Artificial feed			52 C [ ]	52 D [ ]

5.3. Pesticides

- Saponin	yes/no	53 A [ ]
- Theodan	yes/no	53 B [ ]
- Brestan	yes/no	53 C [ ]
- Other	yes/no	53 D [ ]
Total cost	Rp	53 E [ ]

5.4. Energy

- Electricity :	Cost for 1 cycle Rp	54 A [ ]
- Oil/Solar :	Cost for 1 cycle Rp	54 B [ ]

5.5. Lime : Cost for 1 cycle Rp .... 55 A [ ]

5.6. Pond preparation cost Rp .... /cycle/Ha 56 A [ ]

5.7. Rent of Land Rp .... cycle/Ha 57 A [ ]

5.8. Labour Cost

Item	Technical	Non Technical		
Permanent labour				
Monthly wage			58 A [ ]	58 B [ ]
Seasonal labour				
daily wage				58 C [ ]
Contract expert (share system)				
Target (tons)				58 D [ ]
%				58 E [ ]

VI. GENERAL

6.1. Credit

- Intam credit	yes/no	61 A [ ]
- Bank	yes/no	61 B [ ]
- Fry pay after harvest]	yes/no	61 C [ ]
- Feed pay after harvest	yes/no	61 D [ ]
- Middleman (Merchant)	yes/no	61 E [ ]
Total credit: Big/medium/small/no 1 2 3 0		61 F [ ]

6.2. Marketing Outlet

Selling to	yes/no	%	
Middleman	....	....	62 A [ ]
Cold Storage	....	....	62 B [ ]
Local	....	....	62 C [ ]
Other	....	....	62 D [ ]

6.3. Marketing Price of main product

Item	Main Size (number/kg)	Price (Rp/kg)		
Shrimp			63 A [ ]	63 B [ ]
Fish			63 D [ ]	63 D [ ]

6.4. Payment system

- Cash on day of harvest 64 A [ ]
- Credit 64 B [ ]
- Mutual agreement on resources supply against shrimp 64 C [ ]
- Other 64 D [ ]

6.5. Standard of living since starting tambak

Big improvement 1/small improvement 2/no change 3/decrease 4 65 A [ ]

6.6. Succession

Farmer children education
Primary school 1/High school 2/Above 3

Child 1 66 A [ ]
Child 2 66 B [ ]
Other Children 66 C [ ]

Interest of some children to do tambak production: yes/no 66 D [ ]

6.7. Main use of benefits (2 main items only)

Build house/rehabilitation	67 A [ ]
Buy gold (material saving)	67 B [ ]
Buy Land/tambak	67 C [ ]
Buy transportation mean	67 D [ ]
Buy house appliances	67 E [ ]
Investment in another business	67 F [ ]
Savings in Bank	67 G [ ]
Haji travel	67 H [ ]
Other	67 I [ ]

6.8. Member of association: Yes/No 68 A [ ]

6.9. Problem evaluation and discussion

	N° problem 1	Small2	Big 3	
Pollution of water				69 A [ ]
Land abration				69 B [ ]
Supply of fry				69 C [ ]
Lack of land				69 D [ ]
Lack of credit				69 E [ ]
Marketing problem				69 F [ ]
Pond management				69 G [ ]
Other				69 H [ ]

7. Farmer opinion about local CPR problem

....
....
....
....

QUESTIONNAIRE

(detailed farm survey conducted in Mekong Delta)

Coding

I. IDENTIFICATION OF FARMS AND GENERAL INFORMATION

1.1. Identification

Zone: .... Village: .... 11A [ ]
Identification number: .... 11B [ ]
Farmer's name: ....

1.2. Production area in hectares

- Shrimp only and all the year 12A [ ]
- Alternance area: shrimp/fish and rice (same year) 12B [ ]
- Polyculture (shrimp and fish together) 12C [ ]
- Paddy field 12E [ ]
- Other cultures 12F [ ]
- Cage culture (specify species and number of cages) 12D [ ]

....

1.3. Is shrimp culture the main source of income of the household?

Yes / No 13A [ ]

	Nb. of farms	%
Yes	91	98%
No	1	1%
n-a	1	1%

- Share of family income due to shrimp culture .... % 13B [ ]

1.4. Farm management

- State managed farm Yes / No 14A [ ]
- Private managed farm Yes / No 14B [ ]
- Other (type: ....) Yes / No 14C [ ]

	Nb. of farms	%
State managed farm	1	1
Private managed farm	80	85
State investment, private management	12	13
n-a	1	1

1.5. Permanent labor force (for all the farm)

- Number of family member 15A [ ]
- Number of wage labor 15B [ ]

Number of family workers	Nb. of farms	%
no family worker	1	1
[1 until 2]	40	43
[3 until 4]	36	39
5 and more	16	17
Total	93	100

II. TECHNICAL DESCRIPTION AND PRODUCTION MANAGEMENT: today or for last year of operation and for ONE CROP

2.1. History of shrimp farming operation

- Started in 19 .... 21A [ ]
- Years of collapse 19 .... 19 .... 19 .... 21B [ ]
- If stopped, which year 19 .... 21C [ ]

Nb of collapse since starting operation	
Long Hoa	> 2
Ly Hoa Hiep	< 1
Long Toan	> 1
Thoi Thuan - Thanh Phuoc	> 2
Ving Ting	> 2
Ta Ank Huong	< 1
Ap Tac Nam Can	> 3

2.2. Know-how about shrimp culture, origin of experience

- From parent/family Yes / No 22A [ ]
- From training Yes / No 22B [ ]
- Self experience Yes / No 22C [ ]
- Other Yes / No 22D [ ]

Origin of experience	Nb. of farms	%
Parent/family	19	20
Training	37	39
Self experirence	83	88
Other (friends, ...)	12	13

2.3. Number of harvest:

rainy season .... 23A [ ]
dry season .... 23B [ ]

Number of crops/year: .... 23C [ ]

2.4. Total shrimp pond area (hectares)

24A [ ]

2.5. Number of ponds

25A [ ]

2.6. Technique description for the farm reference pond

Item	For the reference pond
Water area (hectares)	.... ha
Depth pond (meter)	.... m
Aeration system	Yes / No
Distance to shore (m)	.... m
Water exchange (in %)	Tidal: ..... % Pumping: ..... % Other: ..... %

coding: 26A [ ]
26B [ ]
26C [ ]
26D [ ]
26E [ ] 26F [ ] 26G [ ]

2.7. Feed for reference pond

Item	Quantity per cycle (Ton per pond)	Cost (Dông/T)
Natural feed		

27A [ ] 27B [ ]

Natural feed : type: .... quantity: .... % 27C [ ]
Artificial feed: type: .... quantity: .... % 27D [ ]

2.8. Shrimp fry supply (source in % and price)

	Source in %	Cost (Dông/T)
- Local harchery - Outside hatchery - Wild		

28A [ ] 28B [ ]
28C [ ] 28D [ ]
28E [ ]

Shrimp fry supply	Nb. of farms	%
Local hatchery	34	36,2
Outside hatchery	50	53,2
Wild	43	45,7

2.9. Shrimp production of reference pond

	Rainy season crop	Dry season crop	Natural shrimps (extensive)
Reference pond area (ha)			
Stocking density (post larvae/ha)			
Echeloned stocking (number of stocking)			
Production (kg/ha)			
Size (pieces/kg)			

coding: 29A [ ] 29F [ ] 29K [ ]
29B [ ] 29G [ ]
29C [ ] 29H [ ]
29D [ ] 29I [ ] 29L [ ]
29E [ ] 29J [ ] 29M [ ]

III. FARM ECONOMICS AND PROBLEM EVALUATION

3.1. Operation costs for one cycle

Item	All ponds (Dông)	Référence pond (Dông)
Labor		
Shrimp fry		
Feed		
Energy (electricity, fuel)		
Land rent		
Equipment rent		
Others (Pesticides, fertilizers, ...)		

31A [ ] 31H [ ]
31B [ ] 31I [ ]
31C [ ] 31J [ ]
31D [ ] 31K [ ]
31E [ ] 31L [ ]
31F [ ] 31M [ ]
31G [ ] 31N [ ]

3.2. Investment

Item	Total cost (Dông)
Building	
Pumping facility	
Paddle Wheel	
Vehicle	

32A [ ]
32B [ ]
32C [ ]
32D [ ]

3.3. Total production cost .... Dông/Kg 33A [ ]

3.4. Cost of wage labor .... Dông/Day 34A [ ]

3.5. Marketing price of shrimp (Dông/Kg).................. 35A [ ]

3.6. Selling to

Item	%	Price (Dông/Kg)
Local		
Export Company		
Other		

36A [ ] 36B [ ]
36C [ ] 36D [ ]
36E [ ] 36F [ ]

Selling to	Number	%
Local	83	88,3
Export company	5	5,3
Other	7	7,4

3.7. Credit

- Bank credit	Yes/No	37A [ ]
- Fry paid after harvest	Yes/No	37B [ ]
- Feed paid after harvest	Yes/No	37C [ ]

Credit	N° of farms	%
Bank credit	36	40,0
Fry paid after harvest	6	6,7
Feed paid after harvest	3	3,3

3.8. Payment of shrimps to the farmer

- Cash on day of harvest	Yes/No	38A [ ]
- Credit	Yes/No	38B [ ]
- Mutual agreement on feed/post-larvae supply against shrimp	Yes/No	38C [ ]
- Other	Yes/No	38D [ ]

Payment of shrimp to the farmer	N° of farms	%
Cash on day of harvest	82	97,6
Credit	2	2,4
Mutual agreement on feed/PL supply against shrimp	3	3,6
Other	3	3,6

3.9. Evaluation of the main difficulties encountered in the recent years

Item	No problem	Small	Big	
Water pollution				39A [ ]
Disease				39B [ ]
Land abrasion				39C [ ]
Supply of fry				39D [ ]
Land				39E [ ]
Credit				39F [ ]
Marketing problem				39G [ ]
Other				39H [ ]

Item	No problem	Small	Big
Water pollution	41	12	47
Disease	46	26	29
Land abrasion	87	9	4
Supply of fry	57	6	36
Land	91	5	3
Credit	60	12	29
Marketing problem	97	0	3
Other	93	2	5

Which one has most affected shrimp farming .... 39I [ ]

4. Farmer opinion about the future of shrimp farming in the area

1 - Very good 40A [ ]
2 - Good
3 - Uncertain
4 - Very bad
5 - No opinion

Village	Very good	Good	Uncertain	Very bad	No opinion
Long Hoa	0%	100%	0%	0%	0%
Ly Hoa Hiep	0%	75%	13%	0%	13%
Long Toan	5%	86%	14%	0%	0%
Thoi Thuan - Thanh Phuoc	31%	77%	23%	0%	0%
Ving Ting	0%	100%	0%	0%	0%
Ta Ank Huong	10%	100%	0%	0%	0%
Ap Tac Nam Can	0%	100%	0%	0%	0%
All farms	7%	85%	8%	0%	1%

5. Request to the administration

.... 50 [ ]
....
....

	all farms		extensive +		extensive	
Request to administration	Nb. of farms	%	Nb. of farms	%	Nb. of farms	%
credit	63	67%	50	64%	13	81%
training	40	43%	37	47%	3	19%
juveniles quality	28	30%	27	35%	1	6%
other	24	26%	19	24%	5	31%

5.1. Shrimp-farming species

1 - Monodon 51 [ ]
2 - Merguiensis
3 - Indicus or Metapenaeus

Shrimp-farming species	N° of farms	%
Penaeus Monodon	72	79,1
Penaeus Merguiensis	29	31,9
Indicus or Metapenaeus	13	14,3

3.3. Results

The methodology presented above has been fully applied to the Indonesian case-study while only the second and third aspects have been developed in the Vietnamese case-study to which much less resource of the project have been affected in terms of socio-economic research. The results of the two case-studies are presented separately in the form of commented figures and tables.

3.3.1. Shrimp farming in Lampung Province (South Sumatra, Indonesia)

Lampung: a fast growing major pole of shrimp culture in Indonesia

Located at the south extremity of Sumatra island (**fig. 59**), Lampung is a growing province with the highest population growth rate in Indonesia and one of the strongest economic growth rate. Its history is directly influenced by the transmigration policy. It is a result of transmigrated population settlement that the shrimp farming has started early in this province.

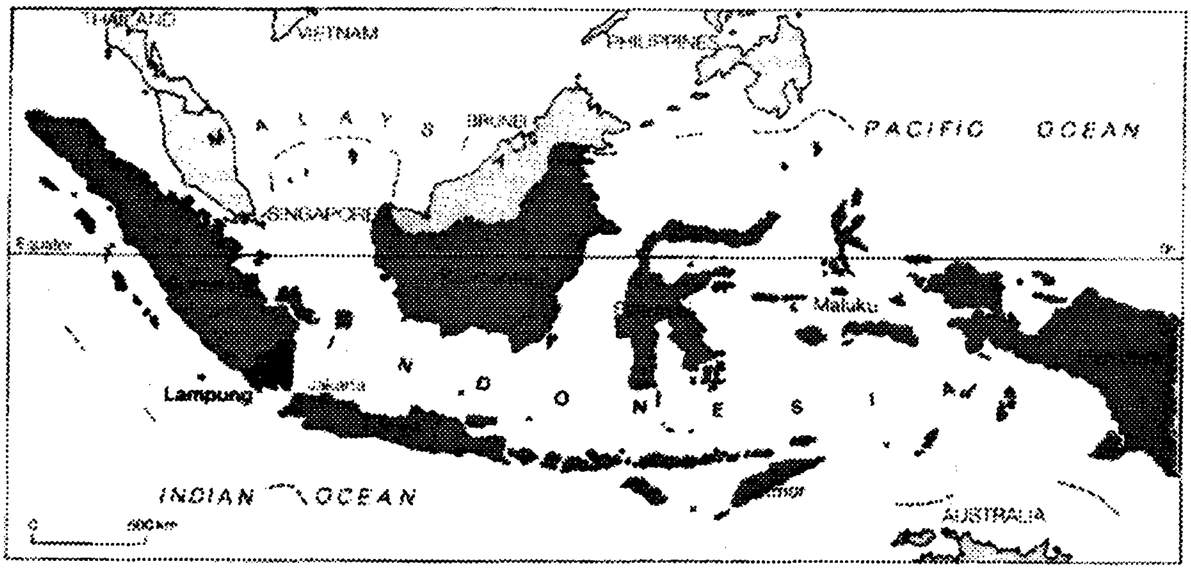


Figure 59. Map of Indonesia.

As the 23 other provinces in Indonesia, Lampung has a local government under the direct authority of a Governor. There are three hierarchic administrative levels. The first one is the Province (Propinsi), the second is the district or regency (Kabupaten) and the last one is the sub-district (Kecamatan). The village (Desa) is not recognised as an administrative level but it plays a very important role is terms of customary law and collective action implementation. Figures 60a, 60b and 61 present the administration structure of Lampung province.

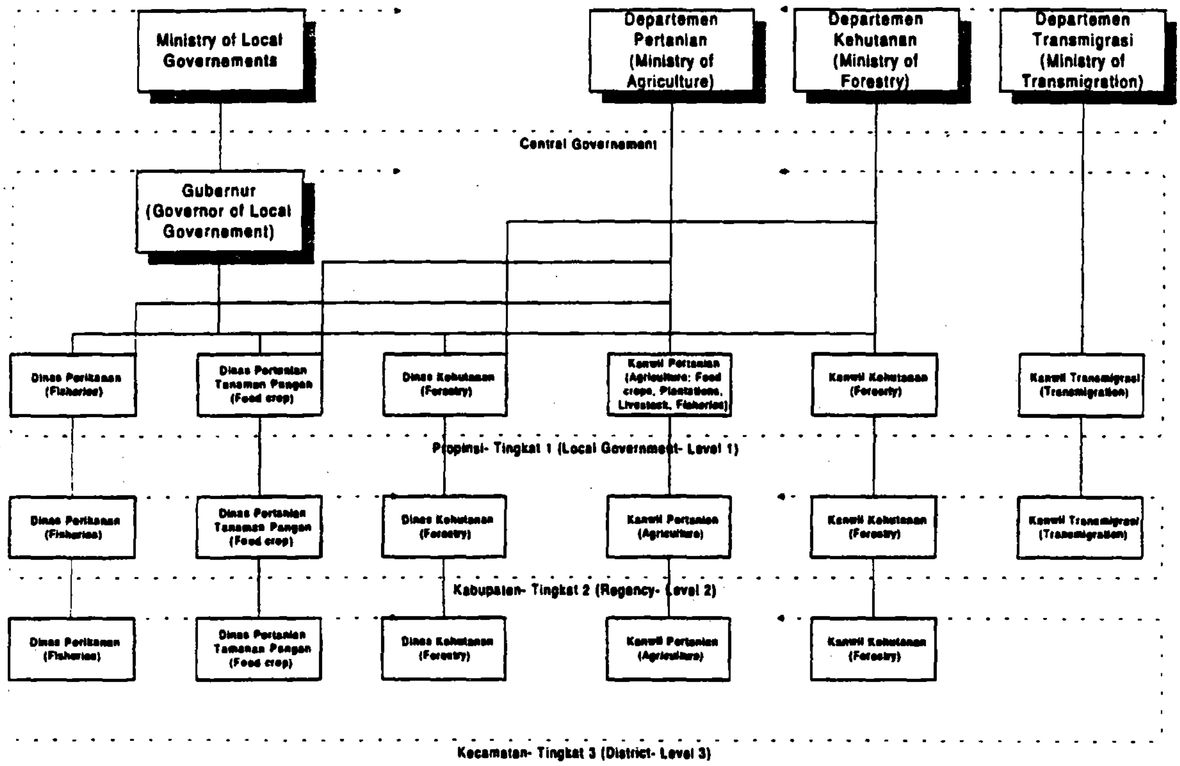


Figure 60a. Administration levels.

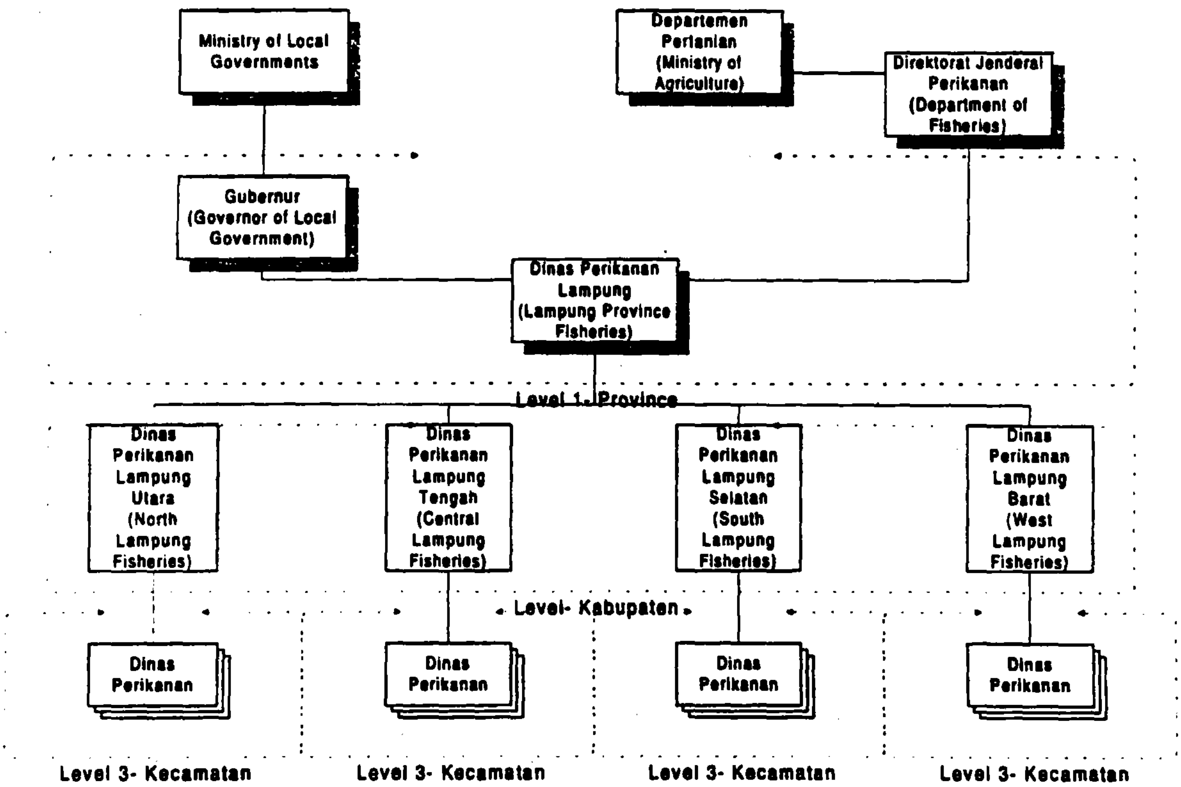


Figure 60b. Fisheries administration in Lampung province.

Figure 61. Main districts in Lampung province.

So, it is in a very dynamic context that the development of shrimp culture started 20 years ago. But it has been very fast only for the past 10 years. Shrimp farming is located along the south coast of the province, mainly in coralline site, and along the Java sea coast where there are two kinds of farms: small scale farms with a major part of villager ownership located in the south-eastern part of the province to be called here Pantai Timur and large scale farms developed as private real estate farms (Dipasena and Bratasena) which operate under the Plasma system (**fig. 62**). The main part of products comes from these Plasma farms (75 %) which applies intensive technique. The farms from the Pantai Timur are less intensive as the average stocking density shows. In majority, the farms located along the south coast are small scale under intensive production systems (**fig. 63**).

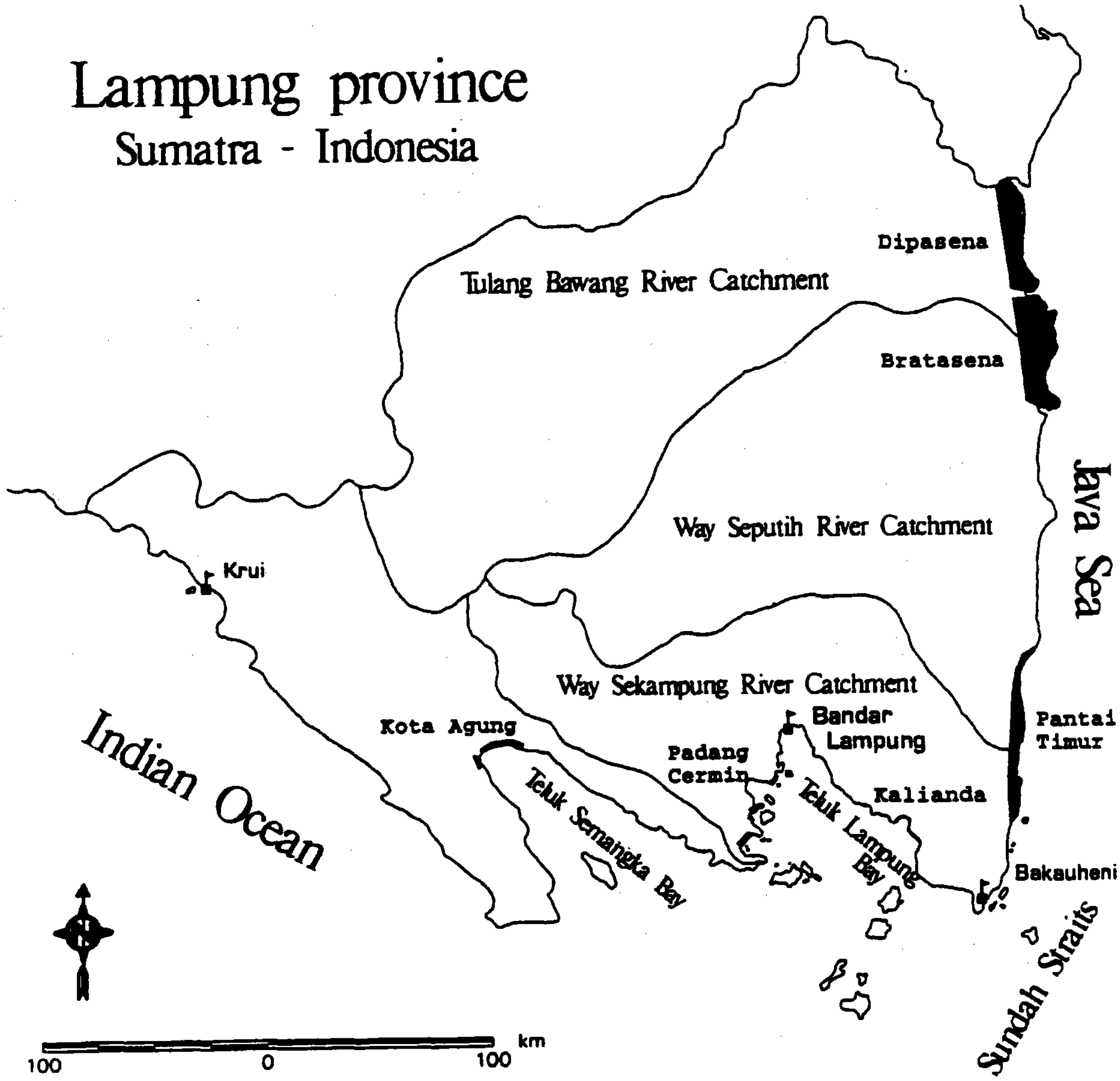
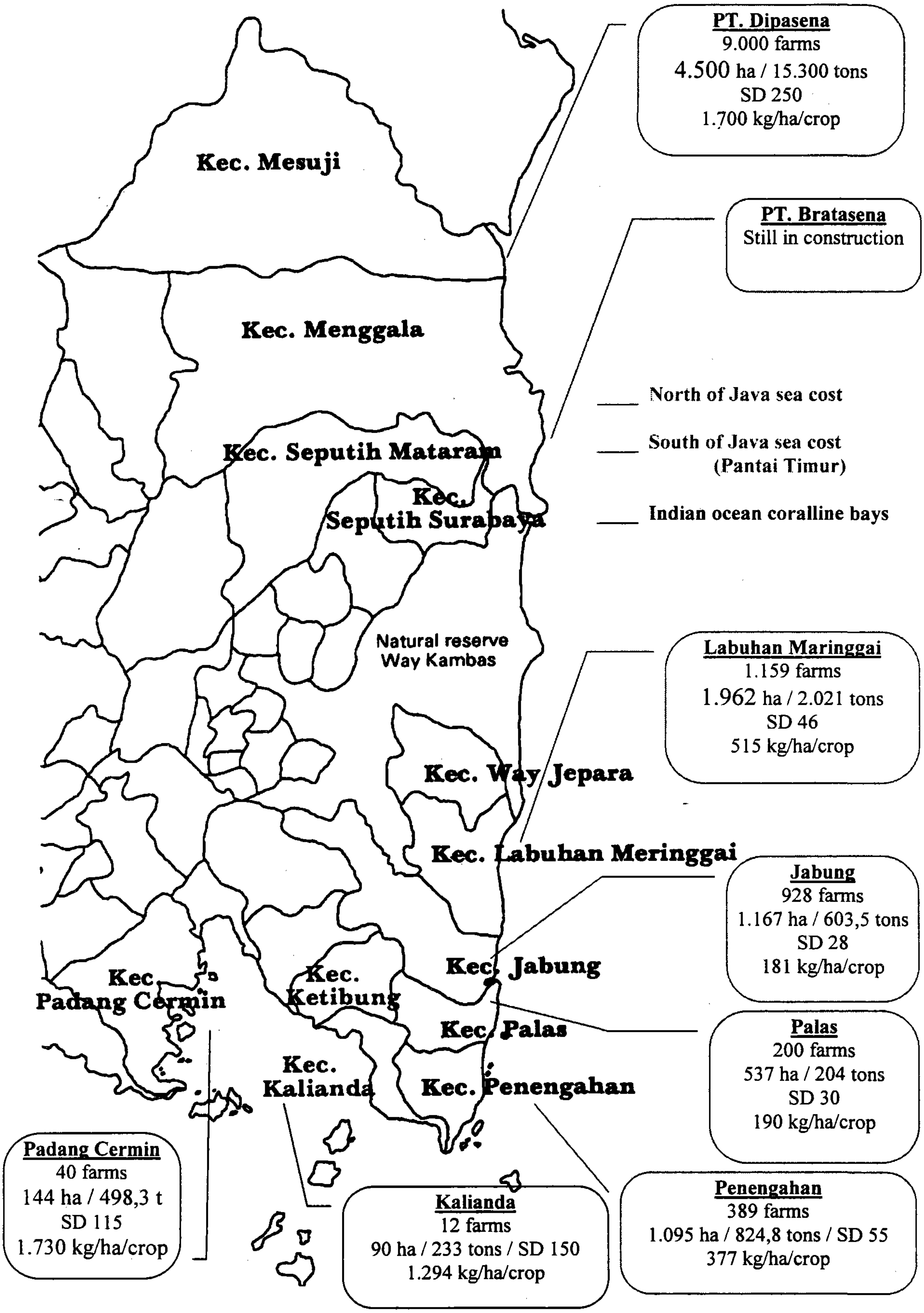


Figure 62. Shrimp farming locations in Lampung province.



SD : Stocking Density in 1.000 PL / ha as a global indicator.

Figure 63. Shrimp farming in Lampung province per main sub-districts (1995 - Dinas Perikanan).

So there are different techniques in shrimp farming. On Lampung province, (and more generally in Indonesia), three levels of intensification are distinguished (**table 39**): Traditional, Semi-intensive and Intensive. A fourth level of intensification can be added: the Traditional + which is officially recorded with the semi-intensive but presents very specific characteristics and is well identified as such by the farmers. The main difference with the traditional is a higher stocking density with supply of artificial feed but without aeration and no major differences in farm structure.

Table 39. Official and real technical criteria in Lampung province.

	Traditional		Semi-intensive		Intensive	
	Official	Real	Official	Real	Official	Real
Stocking density	<2/m^2	2-5/m^2 average3/m^2	4-6m^2	until 15/m² average 10/m^2	>10 m^2	<50/m^2 average 20-30/m^2
Feed (artificial pellets)	no	after 1 month < 100kg/ha	yes	yes	yes	yes
Usual FCR	-	-	-	1-1,5	-	> 1,5
Liming	yes	<500 kg	<1t/ha	-	yes	yes
Fertilisers	100-150 kg/ha	-	yes	yes	yes	yes
Pesticides	yes	yes	yes	yes	yes	yes
Other input	no	corn, rice brain...	no	no	yes	feed complement, fertilisers...
Paddle-wheel	no	no	no	sometimes 1-2/ha<10h/day	yes	>20h/day
Size at harvest	-	10-30p/kg	-	30-35p/kg	-	>35p/kg
Pumping	no	sometimes	yes	yes	yes	yes
Number of crops per year	2-3	2-3	2	2	2	2
Duration of crop	<120 days	< 120 days	120 days	120 days	120 days	120 days
Comments		nursery ponds for post-larvae				

Since 1989, the increase in pond area, number of farm and shrimp production are clearly correlated (**fig. 64**). There is a both a global development by space extension and shrimp farming intensification along the province coastline.

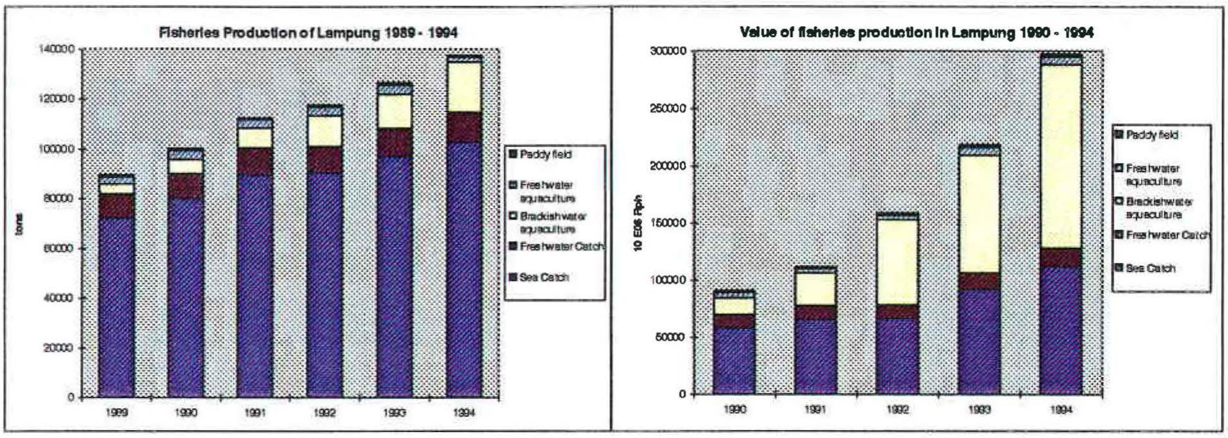


Figure 64. Production and values of fisheries in Lampung province.

Since 1990, the production in value of brackishwater aquaculture presents a strong growth compared to other aquatic primary productions **(fig. 65)** showing the dynamism of shrimp farming development and the key economic it may have in the local economy.

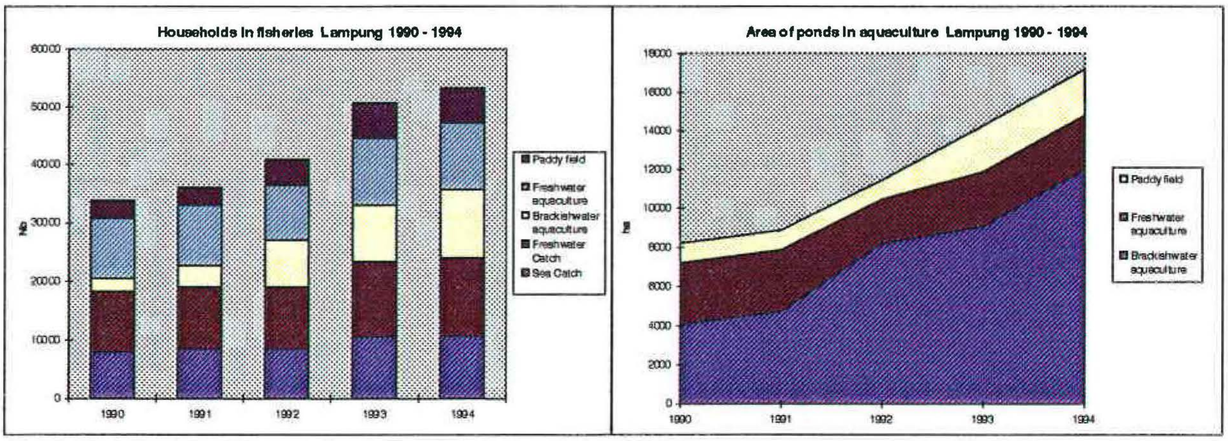


Figure 65. Households in fisheries and ponds area in Lampung province.

The position of Lampung province in the national exports of shrimps shows how fast this growth has been since the beginning of the nineties. Before than, Lampung province production was negligible (**tables 40 and 41**).

Table 40. Shrimps exportations (head-less) - unit: tons.

Province	1992	1993	1994	1995	% 94/95
JAKARTA	11 705	12 114	13 514	10 947	-19%
MEDAN	14 193	13 669	14 226	12 114	-15%
SURABAYA	25 992	22 152	18 308	18 164	-1%
BANDAR LAMPUNG	2 807	6 652	8 387	10 194	22%
Sub Total	54 697	54 587	54 435	51 419	-6%
Oyhers	45 758	43 952	45 088	58 651	30%
INDONESIA	100 455	98 359	99 523	110 070	11%

Source: Fisheries Statistics of Indonesia ; Jakarta March 1996

Table 41. Contribution to shrimps exportations.

Quantity	Year						
(tons)	1989	1990	1991	1992	1993	1994	1995
Indonesia Exportations	77 190	94 037	95 626	100 455	98 569	99 523	110 070
Lampung Exportations	0	300	1 200	3 000	6 651	8 387	10 194
%	0	0,3	1,3	3	6,8	8,4	9,3
Value	Year						
(1,000 US$)	1989	1990	1991	1992	1993	1994	1995
Indonesia Exportations	556 760	690 230	769 982	764 849	876 703	1 009 738	1 137 540
Lampung Exportations	0	2 500	10 000	30 000	90 000	87 800	137 000
%	0	0,4	1,3	3,9	10,3	8,7	12

Source: Fisheries Statistics of Indonesia - February 1996

The development of shrimp farming both supports the development of input industries (post larvae and feed) as well as the processing and marketing sector. Both side are to a large extend external to the province limits. Only the hatchery production is significant locally. For the production, exports are the main destination of shrimps as for most of the production of tropical shrimp in the world. The **figure 66** gives a global view of the links and quantifies the flows among the main groups of agents of the shrimp industry in the province and out of the province. It also offers a synthetic view of a group analysis of shrimp farm that has been conducted on the basis of the 1 000 farms surveyed by the mean of the general farm survey. Number of farms and total contribution of each group (area, production and employment) have been estimated from the results of the survey or by using existing statistics. This view of the industry in Lampung province is a photography of the situation in 1995-1996. Knowing the dynamism of development but the extreme uncertainty attached to shrimp farming, this should be considered as a very static view that might change very rapidly.

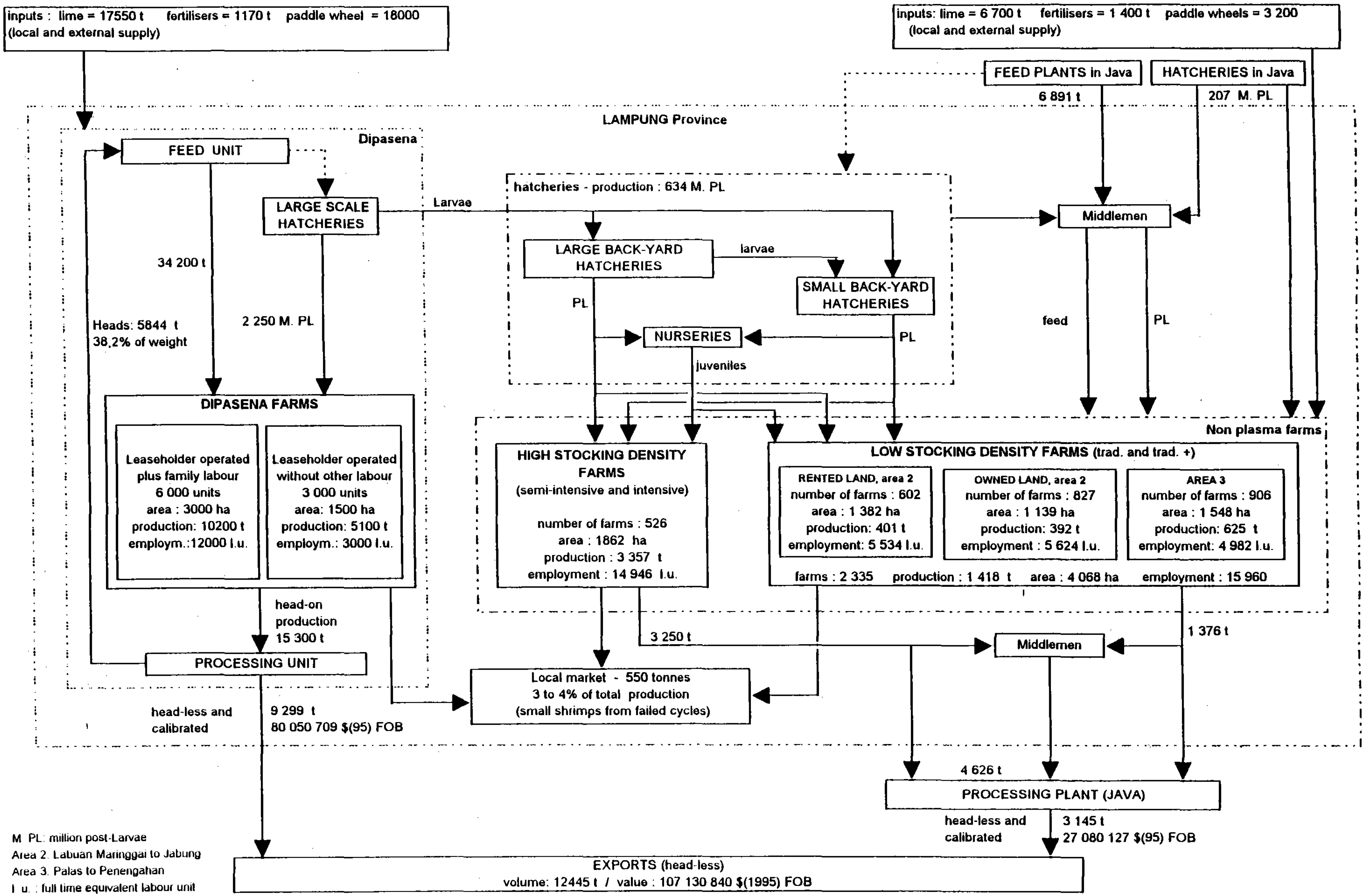


Figure 66. The shrimp industry in Lampung Province.

The group analysis of farms shows three major groups. The first are the farms mainly located in the Pantai Timur area. They are small scale and low stocking density farms with an important share for family labour (**table 42**). They apply traditional or traditional plus techniques and suffer of a difficult access to capital and know-how. It is an endogenous development with little external support based on the resources available at the village level. They use very limited infrastructure for water circulation and they are very sensible to environmental problems.

Table 42. Low stocking density farms characteristics.

Low stocking density farms		Typical farm	
Number of farms	2 335	Average area (ha)	2,6
Total area (ha)	4 068	Average production (tons)	1,05
Total production (tons)	1 418	Stocking density (1.000 PL/ha)	35
Employment (full time equivalent labour unit - lu) family labour seasonal labour permanent labour	15 960 6 161 2 117 7 678	Price (1.000 Rp) Size (shrimps per kg)	16 35

The farms of the second group are those of the coralline bays of the southern coast and some of the eastern coast. They apply high stocking density in semi-intensive or intensive production. They are not necessary run by their owners and the investors is not always a local person. They employ about the same number of full time equivalent labour units for a four times less farms than the previous group, more than the double in production and less than half in pond area. 85 % of the labour is permanent wage labour (**table 43**).

Table 43. High stocking density farms characteristics.

High stocking density farms		Typical farm	
Number of farms	526	Average area (ha)	5,3
Total area (ha)	1 862,5	Average production (tons)	9,56
Total production (tonnes)	3 357,8	Stocking density (1.000 PL/ha)	171
Employment (full time equivalent labour unit - lu) family labour seasonal labour permanent labour	14 946 790 1 263 12 948	Price (1.000 Rp) Size	16,9 33

The third group is the farms operated under the plasma system. They are sites in the north east of the province developed in very remote and unused areas. Two private companies have developed very extensive areas of ponds in a very integrated way (water system management, hatcheries, feed production, processing plant, shipping facilities), applying the best known technologies. Small lots of ponds are leased to individual farmers in charge of their management under the technical guidance of the developer staff. This system of partnership between a site developer and individual farmers is called the plasma system. 9 000 lots of 0.5 ha are leased by Dipasena company (DCD) to individual farmers in 1996. They produced 15 000 tonnes of shrimps. The technique applied is intensive production in earth pond with plastic liner. More recently developed, Bratasena company (CPB) objective for 2001 is to have

15.000 units of 0.5 ha of intensive production in earth ponds with plastic liner and a recirculation system (**fig. 67**).

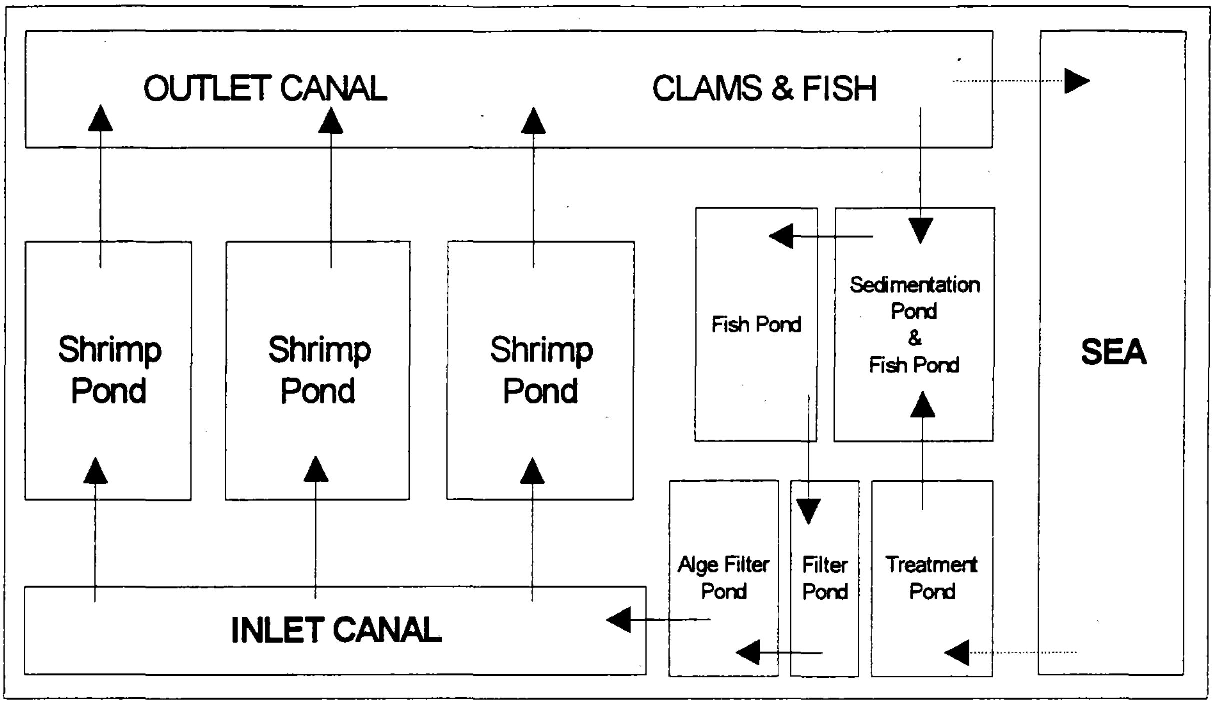


Figure 67. Bratasena recirculation system.

Figure 68 summarises the complex process of farmer selection, training and installation by the site owner.

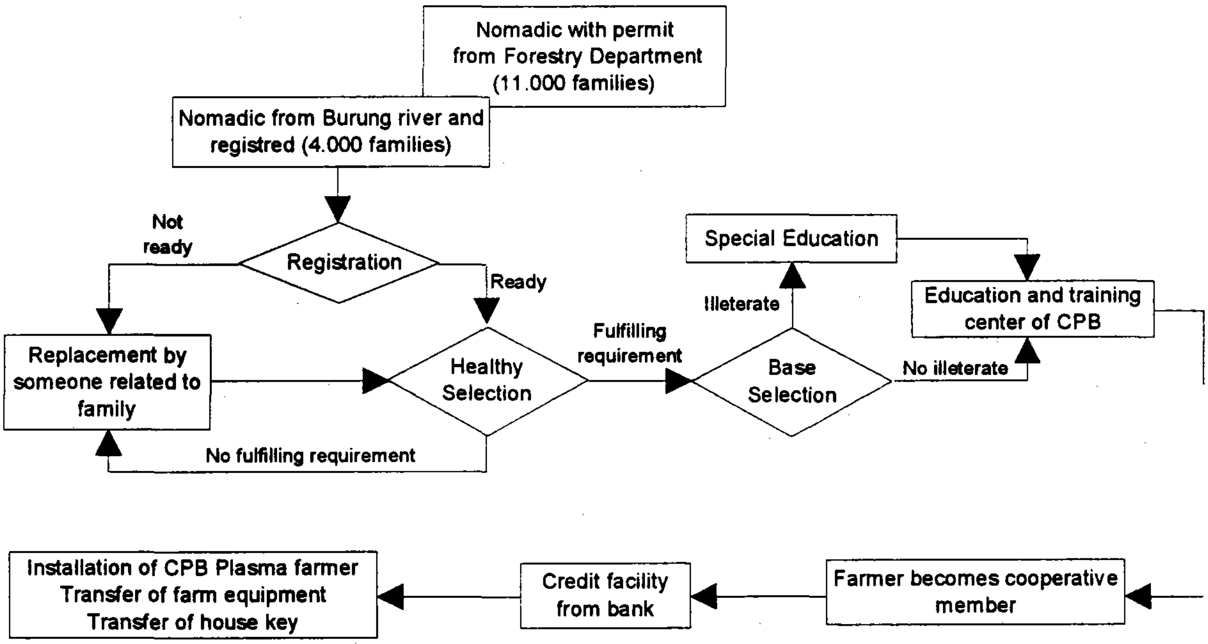


Figure 68. Bratasena process Plasma.

Figures 69, 70 and 71 are the prospective plan of CPB managers with the objective to produce more than 70 000 tonnes of shrimp in 2001. They are self explanatory of their high expectations for the development of shrimp production. If this very optimistic objective is reached, the two companies together will produce almost the equivalent of today's Indonesian production.

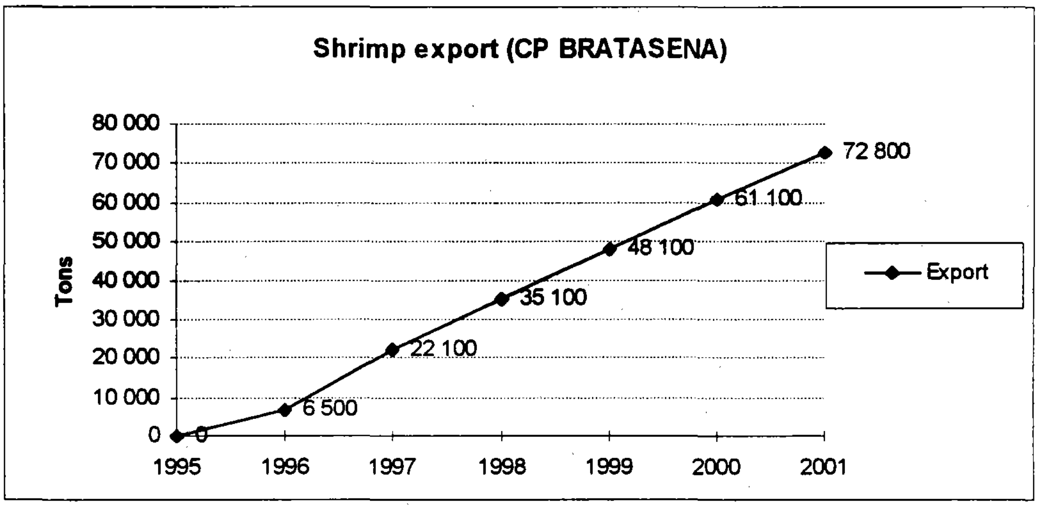


Figure 69. CPB shrimp export forecast.

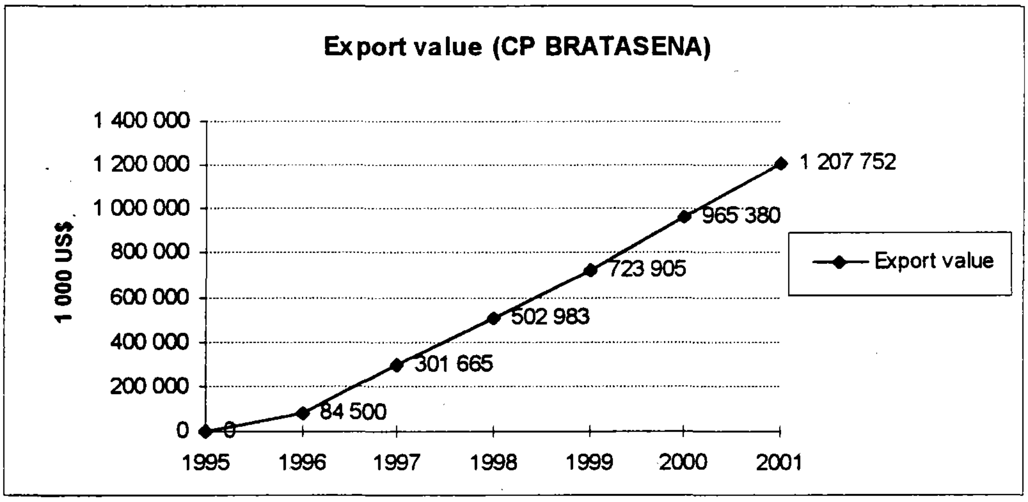


Figure 70. CPB export value forecast.

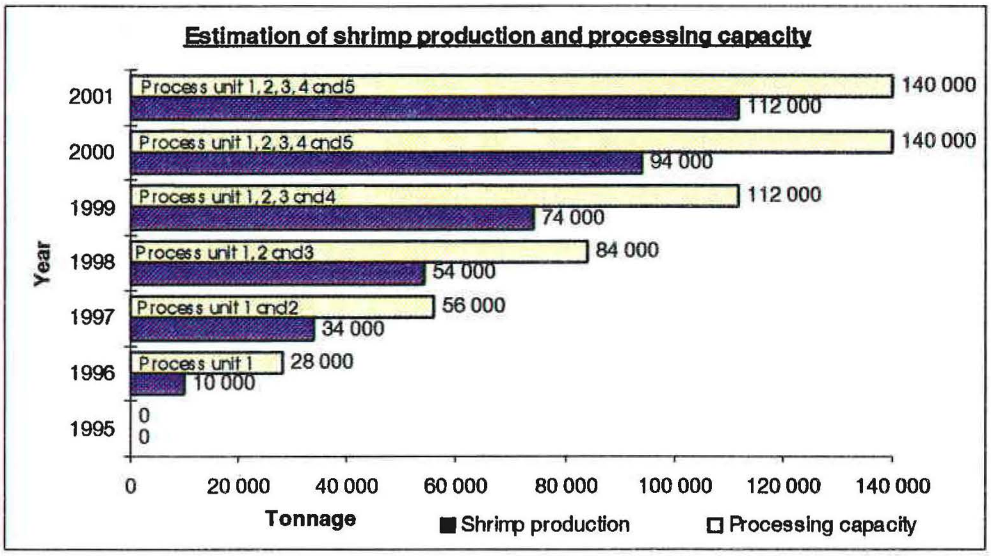


Figure 71. Shrimp production and processing capacity forecast (CPB).

Before any of these targets is reached, the contribution of each group to the economy of shrimp production in Lampung province was as indicated in **table 44** in 1995 without the 400 tons produced by Bratasena.

Table 44. Production and employment for the main profiles.

	Dipasena	High stocking density farms	Low stocking density farms
Production (tons)	15.300	3.358	1.418
%	75 %	16 %	7 %
Employment (full time equivalent labour unit - lu)	15.000	14.946	15.960
%	32,7 %	32,6 %	34,7 %
Employment / Production (lu per ton)	0,98	4,45	11,25

The following tables and figures uses cost and benefit data collected in the 99 farms surveyed for the detailed farm survey. They are the basic technical and economic descriptors of an investment in a production venture. Four levels of intensification have first been used to compare their performances : traditional (T), traditional + (T+), semi-intensive (S-I) and intensive (I) **(table 45)**

Table 45. Economic comparative analysis of production systems by level of intensification.

	T	T+	S-I	I
Farm area (ha)	2,5	2,9	2,9	4,9
Stocking density (1.000 fry/ha)	26	45	115	239
Production per crop (Kg/ha)	312	514	1569	2335
Technical efficiency (Kg/1.000 fry)	12,38	11,46	13,79	10,11
Price (1.000Rp/kg)	16,6	16,7	17,2	17,1
Total cost (1.000Rp/kg)	7,2	11,2	8,2	7,8
Benefit (1.000Rp/kg)	9,4	5,5	9,0	9,3
Investment (1.000 Rp/ha)	5543	8542	17791	20979
Profit/ha/crop (1.000 Rp/ha)	3034	3045	14746	23,50
Profit rate	56,3 %	33,1 %	52,2 %	54,1%
Profit/total cost	1,48	0,59	1,21	1,38
Profit/operational cost	1,60	0,64	1,35	1,50
Depreciation/operational cost	0,08	0,07	0,11	0,09
Depreciation/total cost	0,07	0,06	0,10	0,08
Operational cost/total cost	0,93	0,94	0,91	0,91
Feed cost/total cost	0,23	0,41	0,56	0,47
PL cost/total cost	0,19	0,12	0,12	0,18
Added value ratio	0,73	0,55	0,66	0,67
IRR (2 crops, 1 year)	6 %	-20 %	41 %	73 %
IRR (6 crops, 3 years)	30 %	26 %	57 %	69 %
Return on investment (months)	11	17	7	5

But comparing the situation of the farms classified semi-intensive and intensive along the south coast or on the eastern coast shows major differences. In fact the highest level of intensification on the east coast is closer to the semi-intensive production on the south coast than to the intensive farms. In **table 46**, the same information has been desegregated by area for these last groups.

Table 46. Economic comparative analysis of production systems by level of intensification and per area.

	Pantai Timur					Coralline Site	
	T	T+	S-I	I	S-I East coast	S-I South coast	I
Farm area (ha)	2,5	2,9	2,3	4,7	3,0	5,0	5,0
Stocking density (1.000 fry/ha)	26	45	112	137	119	125	282
Production per crop (Kg/ha)	312	514	1 490	1 483	1 488	1 883	2 700
Technical efficiency (Kg/1.000 fry)	12,38	11,46	13,42	10,36	12,59	12,59	10,00
Price (1.000Rp/kg)	16,6	16,7	17,4	17,4	17,4	16,5	16,9
Total cost (1.000Rp/kg)	7,2	11,2	8,5	8,6	8,5	7,0	7,5
Benefit (1.000Rp/kg)	9,4	5,5	8,8	8,8	8,8	9,5	9,4
Benefit/cost ratio	1,48	0,59	1,14	1,16	1,15	1,48	1,48
Investment (1.000Rp/ha)	0,73	0,55	0,64	0,65	0,65	0,71	0,68
TRI (2 crops, 1 year)	5 543	8 542	16 033	11 138	14 698	24 821	25 197
TRI (6 crops, 3 years)	6 %	-20 %	41 %	73 %	41 %	41 %	73 %
Return on investment (months)	30 %	26 %	61 %	75 %	64 %	44 %	68 %
	11	17	7	5	6	8	6
Profit rate	56,3 %	33,1 %	50,8 %	50,7 %	50,8 %	58,0 %	55,5 %
Profit/total cost	1,48	0,59	1,14	1,16	1,15	1,48	1,48
Profit/operational cost	1,60	0,64	1,26	1,25	1,26	1,72	1,61
Depreciation/operational cost	0,08	0,07	0,10	0,11	0,10	0,15	0,09
Depreciation/total cost	0,07	0,06	0,09	0,09	0,09	0,13	0,08
Operational cost/total cost	0,93	0,94	0,91	0,89	0,91	0,88	0,92
Feed cost/total cost	0,23	0,41	0,56	0,50	0,55	0,52	0,46
PL cost/total cost	0,19	0,12	0,11	0,15	0,12	0,13	0,19
Profit/ha/crop (1.000 Rp/ha)	3 034	3 045	13 845	14 696	14 077	18 350	26 630

Table 47 compares the structure of the sample in terms of profit rate level for each level of intensification.

Table 47. Profit rates per technique.

Profit rate %	T	T+	S-I	I	Total
0 to < 20%	3,0 %	17,4 %	5,0 %	0 %	6,3 %
20 to < 40%	0 %	43,5 %	0 %	15,0%	13,5 %
40 to < 60%	60,6 %	34,8 %	70,0 %	50,0 %	54,2 %
> 60%	36,4 %	4,3 %	25,0 %	35,0 %	26,0 %
Total	100 %	100 %	100 %	100 %	100 %

Tables 48 and **49** compares the cost and revenue structure in Rp/ha, in absolute value and in percentages, of semi-intensive production in both areas. **Table 50** gives a similar comparison among all levels of intensification and expressed in Rp/kg.

Table 48. Cost and revenue structure of production system in Rp per ha.

	S-I East coast	S-I South coast
Feed	6 859 813	6 566 500
Fry	1 331 250	1 562 500
Lime	234 844	215 000
Pesticides	134 250	112 500
Energy	143 873	194 792
Pond preparation	732 500	500 000
Labour	1 616 250	1 811 125
Labour + pond	2 348 750	2 311 125
Land rent	0	0
Operational cost	11 052 780	10 962 417
Depreciation	1 128 145	1 627 605
Total cost	12 180 924	12 590 021
Profit	13 844 951	18 350 229

Table 49. Cost and revenue structure of production system in % from Rp/ha.

	S-I East coast	S-I South coast
Feed	26,4	21,2
Fry	5,1	5,1
Lime	0,9	0,7
Pesticides	0,5	0,4
Energy	0,6	0,6
Land rent	0,0	0,0
Labour + pond prep.	9,0	7,5
Depreciation	4,3	5,3
Profit	53,2	59,3
	100,0	100,0

Table 50. Cost structure of production systems - Rp / Kg : 1 crop.

profit rate %	T	T+	S-I	I
Feed	1 649	4 530	4 615	3 641
Fry	1 285	1 304	924	1 391
Lime	268	313	159	166
Pesticides	436	329	91	93
Energy	231	307	114	232
Pond preparation	883	1 047	467	601
Labour	1 388	1 942	1 060	920
Labour + pond preparation	2 271	2 989	1 527	1 521
Land rent	552	701	0	51
Operational cost	6 692	10 474	7 430	7 095
Depreciation	516	694	772	700
Total cost	7 208	11 168	8 202	7 795
Profit	9 413	5 538	8 988	9 255

Figures 72 and **73** compares in absolute values and in percentage the structure of investment per hectare for each of the four levels of intensification. **Figures 74** and **75** illustrate the tendency toward intensification within all groups followed by an increase in technical efficiency with the only exception for the traditional plus. This group of farms shows all the signs of major difficulties.

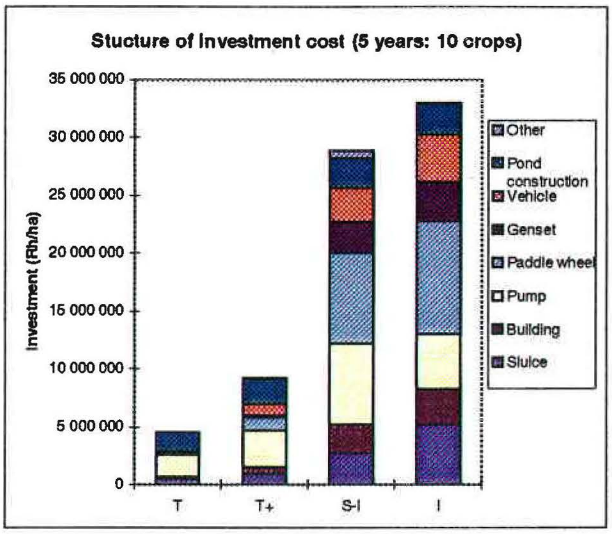


Figure 72. Structure of investment (Rp/ha).

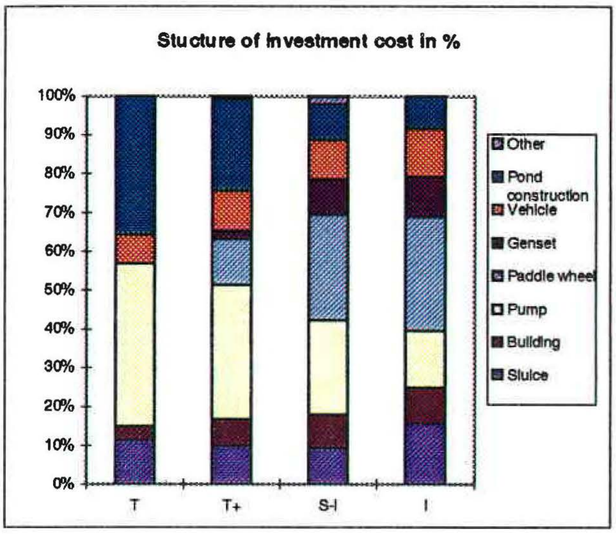


Figure 73. Structure of investment (%).

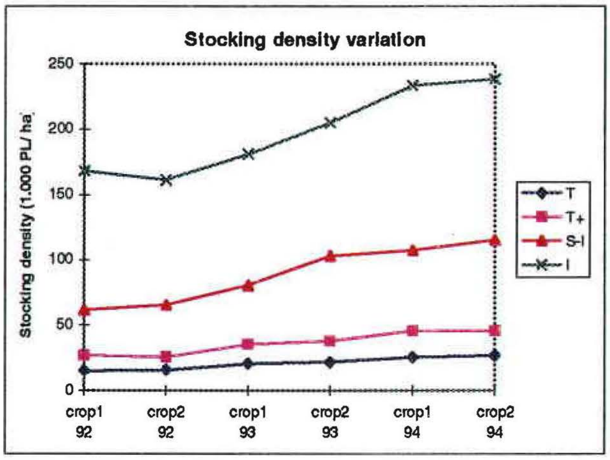


Figure 74. Stocking density variation.

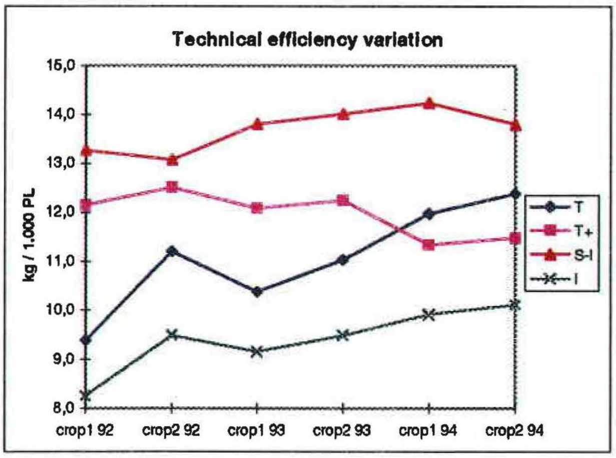


Figure 75. Technical efficiency variation.

The increase of stocking density has been measured on a time span of 6 crops (three years). Excepted for the intensive production, the increase is above 70 % **(table 51)**. This is consistent with the high returns calculated above but also indicates the dynamism of the intensification process under this intensive.

Table 51. Variation of stocking density per technique.

	crop1 92	crop2 94	Evolution
T	15	26	77 %
T+	27	45	70 %
S-I	61	115	88 %
I	168	239	42 %

The survival rate in commercial production condition seems very low compare to ordinary experimental figures or even to the figures claimed by some international groups. It is below 50 % in average for all techniques if with include in the calculation the collapsed crop. This approach is the only consistent in terms of farm management and risk analysis. But still this figures are far above the break-event survival rate **(table 52)**.

Table 52. Survival rate & Break event point per technique.

	Survival rate (6 crops average)	Break event point (6 crops average)
T	37,5%	17%
T+	41,5%	25%
S-I	44,0%	20%
I	30,2%	13%

The traditional + group appears in average the most threaten by the risks attached to shrimp production (**table 53**). Whatever the reason is, intensification above the local potential of the ecosystem, inappropriate pond management or water supply, this group must be analysed in detail. Particularly because it is also the group showing the highest standard error for many parameters. Discriminating the farms with the best returns from those with the worst performance leads to the conclusion that profitability is link to the somehow contradictory phenomena of high technical performance (efficiency) and low operational cost. This is a very preliminary conclusion that would request the type of analytical approach referred in the introduction to obtain more conclusive results.

Table 53. Comparative analysis of traditional + technique.

Traditional + all costs in Rp/1.000 PL	Low efficiency High operational cost farms	High efficiency Low operational cost farms	Variation %
Stocking density (PL/m2)	43	48	-10
Production (kg/ha)	379	644	-41
Technical efficiency (kg/1.000 PL)	8	13	-56
Fry	695 282	562 500	19
Feed	2 518 804	1 865 000	26
Pesticides	187 375	147 500	21
Energy	147 793	207 083	-40
Lime	157 874	131 250	17
Land rent	645 847	0	100
Seasonal labour	472 027	244 000	48
Permanent labour	560 577	647 500	-16
Total labour	1 032 604	891 500	14
Depreciation	247 503	380 354	-54
Operational cost	5 943 719	4 192 333	29
Total production cost	6 191 222	4 572 688	26
Profit (Rp/1.000 PL)	992 832	6 171 063	-522
Benefit/cost ratio	0,18	1,35	-87
Price (Rp/kg)	16 929	16 750	1
Added Value (Rp/kg)	7 053	12 160	-42
Added value ratio	0,42	0,73	-42
share of labour	23,5 %	11,9 %	97

The analysis of the shift operated by the farmers from one level of intensification to another one since they started shows that two groups are very stable. Traditional and intensive operation are generally an initial and definitive choice. While traditional + or semi-intensive operation is the result of a progressive approach toward intensification (**table 54**).

Table 54. Technical change

Technical change		Number	Changes in technique	
Traditional	T	30	0	0%
Traditional +	T+	30		
change :	T --- T+	28		
no change :	T+ --- T+	2		
			28	93%
Semi Intensive	SI	30		
change :	T --- SI	6		
	T+ --- SI	3		
	T --- T+ --- SI	16		
no change :	SI --- SI	5		
			25	83%
Intensive	I	10		
change :	T+ --- SI --- I	1		
no change :	I --- I	9		
			1	10%
TOTAL		100	54	54%

A first sign of the profitability of shrimp business is the rapid increase of land price with the development of this production (**figure** 76).

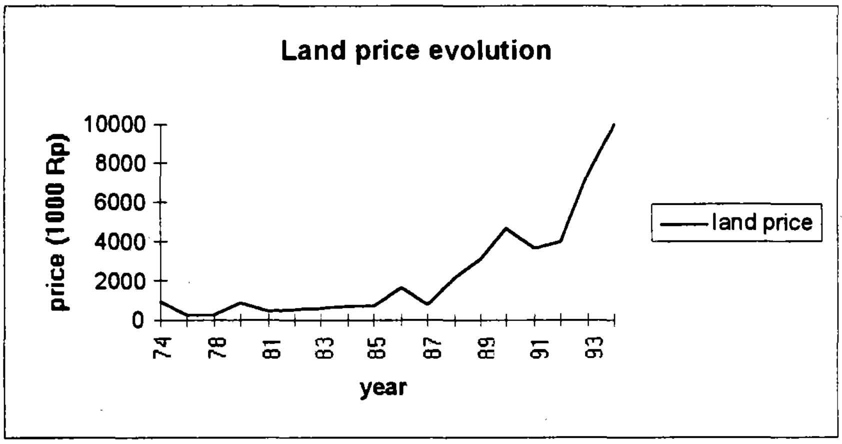


Figure 76 : Land price evolution.

The farmers have been questioned about the difficult they have to ensure the viability of their activity. This covers both internal management or structural problems and environmental risk. The results are presented by level of intensification (**table 55**) and by area (**table 56**). The dominance of environmental stress to explain uncertainty of shrimp production over the mismanagement as a cause of collapse reveals two phenomena. The first is the real importance of the environmental issues but the second is the probably excessive confidence of the farmers in the way they manage their production. The lack of access to capital appears also as a major constraint in a industry where high returns is an incentive to invest. This constraint might be interpreted as positive as the only force to limit the speed of development. Marketing is by no mean a difficulty. Other aspects are variable according to the location or type of farm.

Table 55. Main troubles encountered per technic (official criteria).

Technic	Troubles	Land certificate	Erosion	Collapse : environmental stress	Collapse : mismanagement	Lack of capital	Market choice
T	yes (%)	64,7	9	85,5	36,8	92,2	0
	no (%)	35,3	92	14,5	63,2	7,8	100
T+	yes (%)	43,5	6	68,7	7	87,9	0,3
	no (%)	56,5	94	31,3	93	12,1	99,7
S-I	yes (%)	25	26,3	43,4	4	71	1,3
	no (%)	75	73,7	56,6	96	29	98,7
I (non include Dipasena)	yes (%)	7,1	33,3	57,1	16,7	28,6	4,8
	no (%)	92,9	66,7	42,9	83,3	71,4	95,2
Dipasena	yes (%)	32	60,7	75,3	31	2	0
	no (%)	68	39,3	24,7	69	98	100
Total	yes (%)	42,8	25,9	72,8	22,4	59,5	0,4
	no (%)	57,2	74,1	27,2	77,6	40,5	99,6

Table 56. Main troubles encountered per area (other areas aren't signifiant).

Area	Troubles	Land certificate	Erosion	Collapse : environmental stress	Collapse : mismanagement	Lack of capital	Market choice
Mesuji Lampung	yes (%)	32	60,7	75,3	31	2	0
(Dipasena)	no (%)	68	39,3	24,7	69	98	100
Labuan	yes (%)	0,9	20	39	2,4	88,5	0
Maringgai	no (%)	99,1	80	61	97,6	11,5	100
Jabung	yes (%)	65,3	14,1	94,7	60,6	95,9	0
	no (%)	34,7	85,9	5,3	39,4	4,1	100
Palas	yes (%)	75,2	2,9	89,5	9,5	76,2	0
	no (%)	24,8	97,1	10,5	90,5	23,8	100
Penegahan	yes (%)	79,4	3,9	74,8	2,6	74,2	0
	no (%)	20,6	96,1	25,2	97,4	25,8	100
Wonosobo	yes (%)	15,8	5,3	84,2	15,8	65,8	5,3
	no (%)	84,2	94,7	15,8	84,2	34,2	94,7
Total	yes (%)	42,8	25,9	72,8	22,4	59,5	0,4
	no (%)	57,2	74,1	27,2	77,6	40,5	99,6

3.3.2. Shrimp farming in the Mekong Delta (Vietnam)

Shrimp farming in the Mekong river delta has been studied in a much less detailed way than in Indonesia. The methodology presented above has been applied only partially. 89 farms have been surveyed using a detailed questionnaire. They are spread along the coast of the delta to get a view of the diversity. But this is at the cost of a low representativity of the samples in each place. This is not a major problem in terms of level of intensification as only the lowest level of intensification are significantly present in the delta. Most attempts to develop semi-intensive or intensive systems have collapsed. As another difference with Indonesia, indigenous species other than the tiger shrimp play a significant role (**table 57**).

Table 57. Shrimp-farming by species (two species per farm is encountered).

Shrimp-farming species	Nb. of farms	%
monodon	72	79,1%
merguiensis	29	31,9%
metapenaeus	13	14,3%

Source: Mekong survey - 1997

Table 58 shows a typical image of the evolution of shrimp farming in the delta with the figures of the leading district. The negative correlation between the extension of the pond area and the productivity is characteristic.

Table 58. Area, production and average yield for Minh Hai province.

Year	Shrimp farms area (ha)	Total production/year (tons/year)	Average yield (kg/ha/year)
1990	60 000	24 500	408
1991	60 000	28 600	476
1992	80 000	31 000	387
1993	119 000	36 400	305
1994	124 000	29 100	234
1995	142 000	31 150	219
1996 (Ca Mau)	105 519	27 700	262

Average yield based on farms area. Water area is 60% of farms area.

Figures on the following pages show the Mekong river catchment basin (**figure** 77), the official records of shrimp production in 1996 in each district (**figure 78**) and a summary of the characteristics of shrimp production as seen from the results of the survey (**figure** 79).

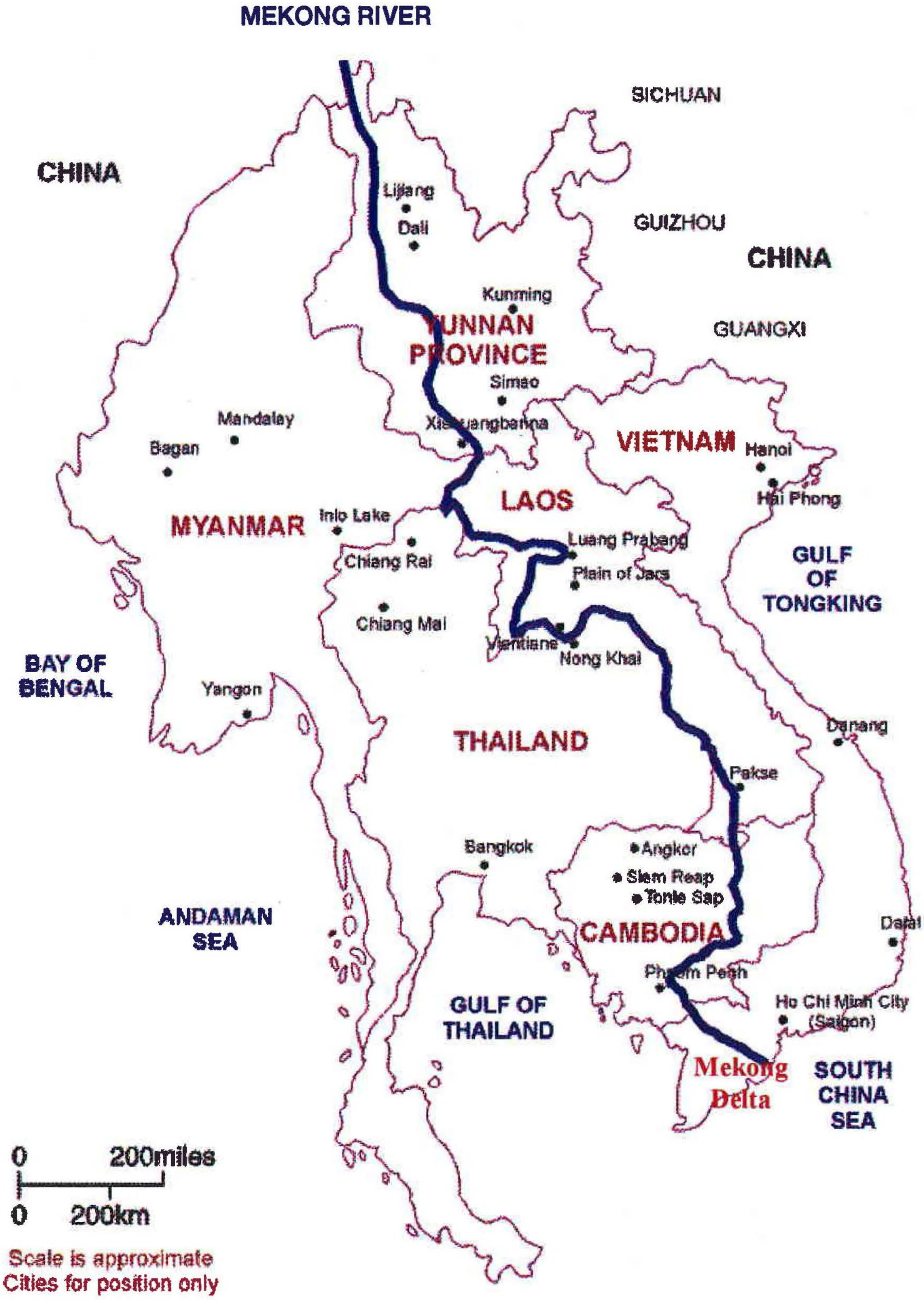


Figure 77. Mekong riverside countries.

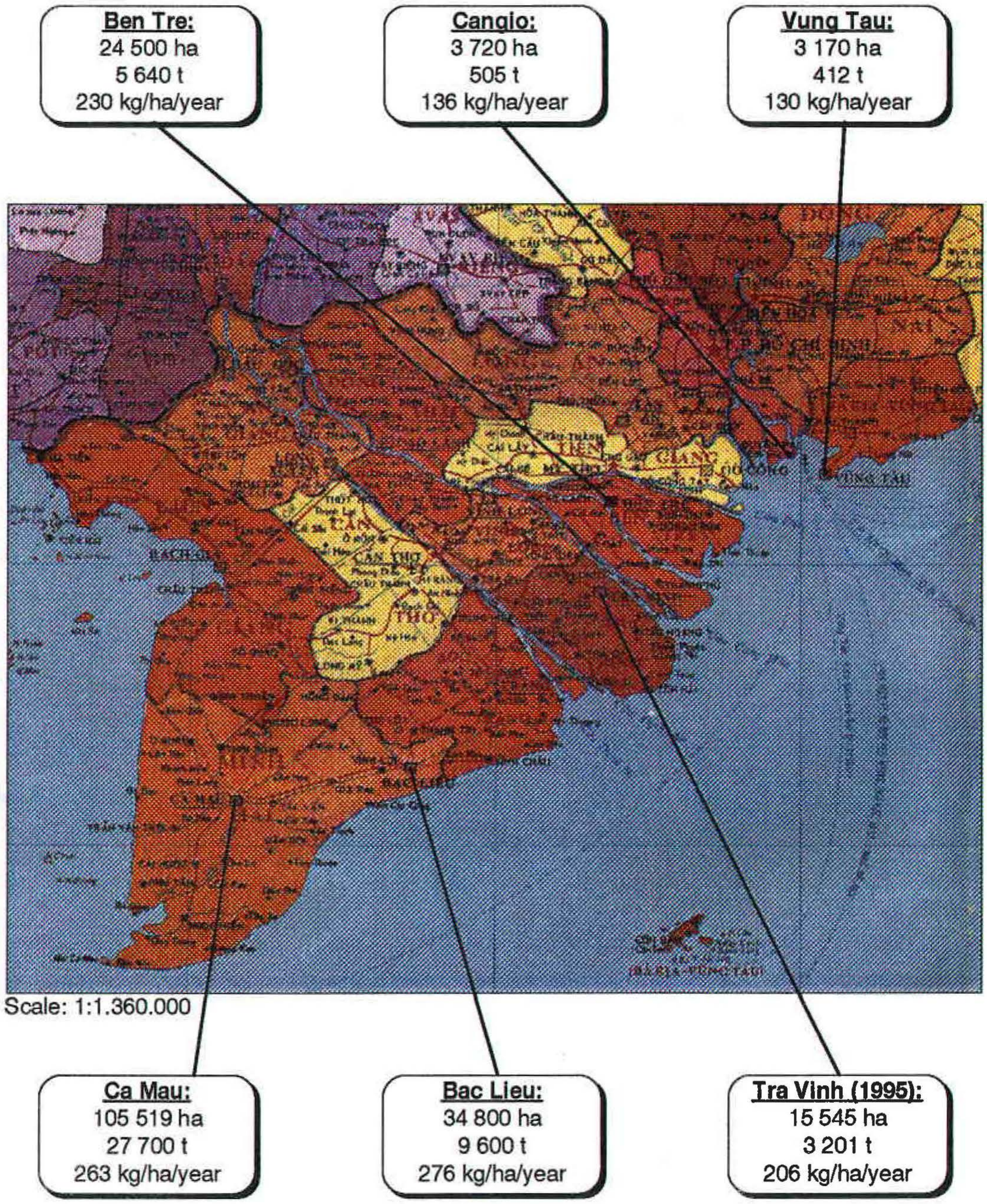


Figure 78. Shrimp Farming on studied sites (1996).

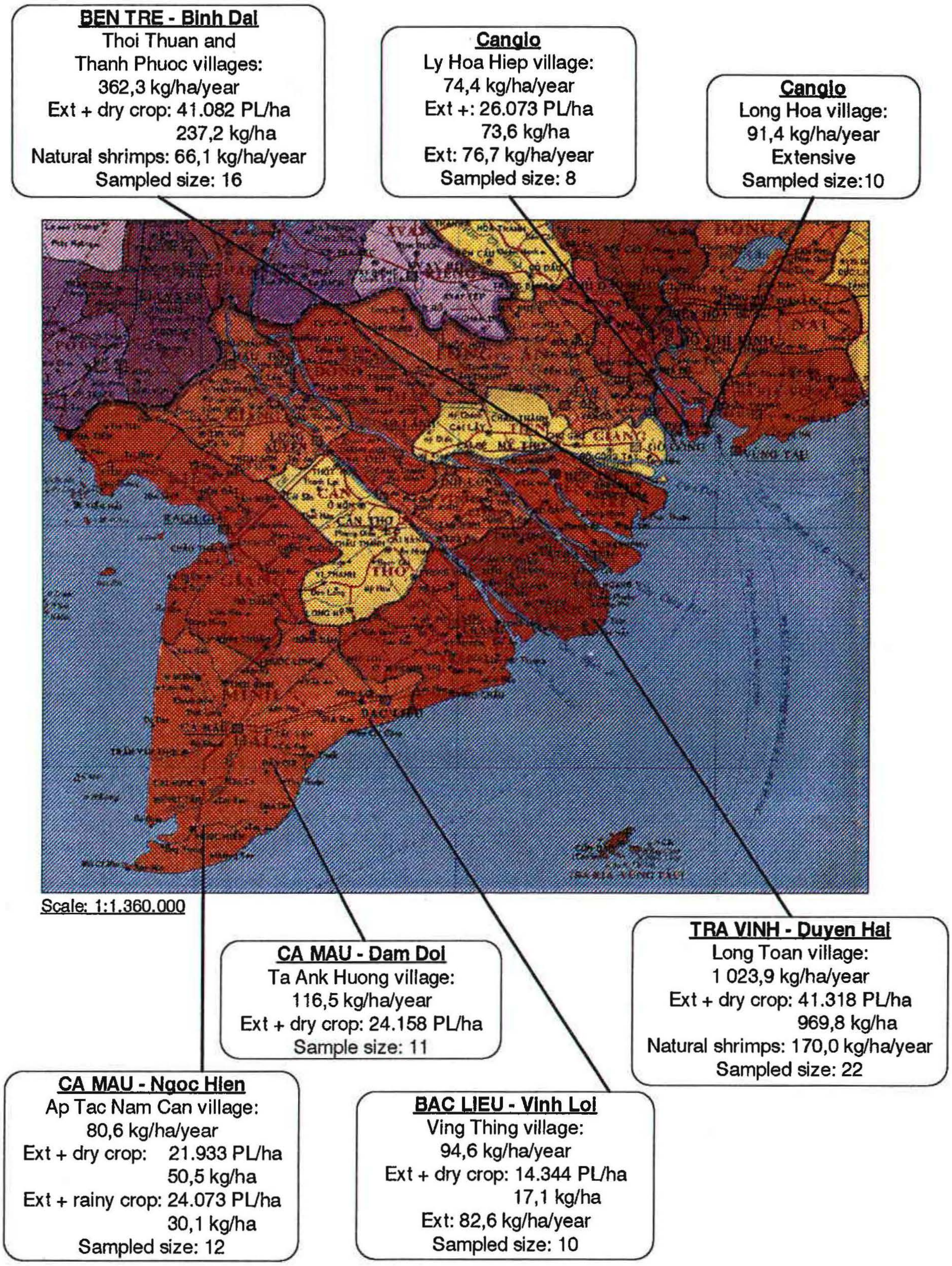


Figure 79. Shrimp Farming on sampled sites (1996).

Tables 59 gives a view of the evolution of shrimp farming productivity per hectare in the delta using the very limited information that could be gathered from the administration. This indicated the very low level of intensification but also the negative trend of productivity as the production expands.

Table 59. Yields evolution per site - Kg/ha/year.

	Vung Tau	Cangio	Ben Tre	Tra Vinh	Minh Hai
1990	-	-	112	-	408
1991	250	-	131	-	476
1992	-	-	169	229	387
1993	220	300	322	183	305
1994	-	-	318	105	234
1995	-	-	260	206	219
1996	130	135	230	-	262 (Ca Mau)

This development has been at the cost of the loss of mangrove areas. Minh Hai province data are a good illustration of this fact (**table 60**).

Table 60. Mangrove forest area and shrimp farming in Minh Hai Province.

Year	Mangrove forest area (ha)	Shrimp farming area (ha)
1983	117 745	3 000
1988	72 989	28 920
1991	49 920	47 840

Source: http://treesandpeople.lbutv.slu.se/newsl/30hansso.htm

Figure 80 shows that the farmers are largely left to themselves to acquire the know-how. 39 % declare to have received some training but this is in most case very limited extension services.

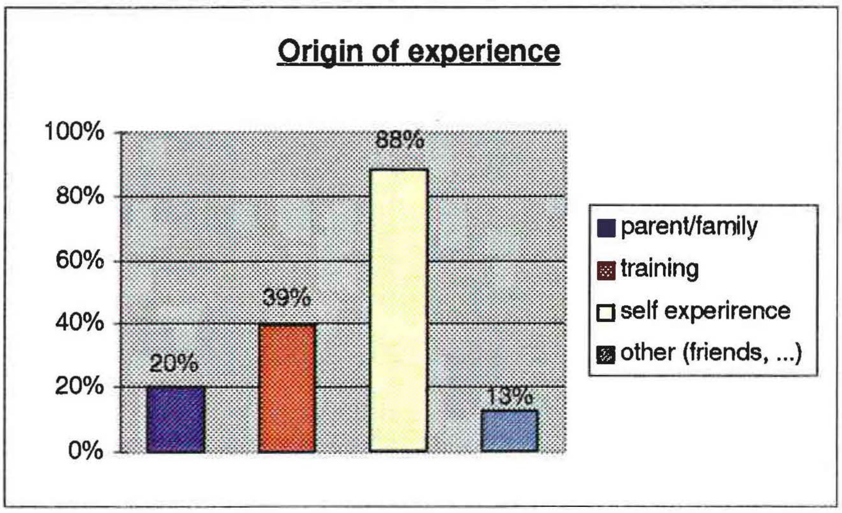


Figure 80.

Using a factorial analysis approach the 89 farm surveyed in the delta have been classified in groups according to technical profiles in each village surveyed to be considered as representative of the situation in their district (**table 61**). Only extensive and extensive +, similar to the traditional and traditional + terms used in Indonesia, are found. The second group can be divided according to differences in rearing practices during rainy and dry seasons.

Table 61. Percentage of farms per village and technique.

Village	Extensive	Extensive +		
		dry season only	dry season natural shrimp	dry season rainy season
Long Hoa	100%	0%	0%	0%
Ly Hoa Hiep	25%	75%	0%	0%
Thoi Thuan - Thanh Phuoc	0%	38%	50%	13%
Long Toan	0%	68%	32%	0%
Ving Ting	30%	0%	70%	0%
Ta Ank Huong	0%	100%	0%	0%

Cost and revenue structure are first summarised by village in Dông/kg (**table 62**) and in percentage for costs (**table 63**).

Table 62. Cost and revenue structure of shrimp production.

Dông per kg (one year operation)

	CANGIO		TRA VINH	BEN TRE	BAC LIEU	CA MAU	
One year operation Dông/kg	Long Hoa	Ly Hoa Hiep	Long Toan	Thoi Thuan Thanh Phuoc	Ving Ting	Ta Ank Huong	Ap Tac Nam Can
Fry	0	35 334	9 767	74 266	56 140	39 050	141 711
Feed	0	2 573	19 194	13 278	15 656	2 008	4 644
Energy	0	0	216	0	31 103	0	0
Land rent	0	762	256	1 302	63 148	7 200	0
Labour	6 258	8 906	190	17 841	9 754	0	0
Other	0	0	573	2 446	1 900	0	0
Operational cost	6 258	47 575	30 197	109 133	177 701	48 258	146 354
Depreciation	103	3 785	6 373	19 422	39 800	21 061	5 459
Total cost	6 362	51 361	36 569	128 556	217 501	69 319	151 813
Price	44 000	90 000	86 496	73 465	15 026	86 500	121 111
Profit	37 638	38 639	49 927	-55 090	-202 475	17 181	-30 702

Table 63. Cost structure of shrimp production (%).

Dg/kg

	CANGIO		TRA VINH	BEN TRE	BAC LIEU	CA MAU	
%	Long Hoa	Ly Hoa Hiep	Long Toan	Thoi Thuan Thanh Phuoc	Ving Ting	Ta Ank Huong	Ap Tac Nam Can
Fry	0%	74%	32%	68%	32%	81%	97%
Feed	0%	5%	64%	12%	9%	4%	3%
Energy	0%	0%	1%	0%	18%	0%	0%
Land rent	0%	2%	1%	1%	36%	15%	0%
Labour	100%	19%	1%	16%	5%	0%	0%
Other	0%	0%	2%	2%	1%	0%	0%
	100%	100%	100%	100%	100%	100%	100%

Comparing economic performance of shrimp production in the villages surveyed shows significant differences even at similar levels of productivity, this being measured by the production per hectare. The term profit used here should be interpreted as a family income rather than a return on investment which is the proper economic definition of profit (**table 64**).

Table 64. Technical and economic data of shrimp production per village.

	CANGIO		TRA VINH	BEN TRE	BAC LIEU	CA MAU	
	Long Hoa	Ly Hoa Hiep	Long Toan	Thoi Thuan Thanh Phuoc	Ving Ting	Ta Ank Huong	Ap Tac Nam Can
Pond area (ha)	8,4	8,5	0,2	4,1	16,6	1,1	1,8
Depth pond (meter)	1,9	1,2	0,95	0,94	0,59	1,04	1,01
Production per year (Kg/ha)	91,4	74,4	1 023,9	362,3	94,6	116,5	80,6
Distance to shore	2 700	16 250	7 205	6 029	1 420	16 091	12 000
Seed price	0	103	230	140	194	152	145
Price: Merguiensis / Indicus	44 000	30 000	21 190	22 037	12 690	0	0
(Dông/kg) Monodon	0	100 000	89 381	85 951	75 000	86 500	114 841
Profit rate	84%	48%	54%	Negative	Negative	13%	Negative
Total cost (Dg/kg)	6 362	51 361	36 569	128 556	217 501	69 319	151 813
Benefit (Dg/kg)	37 638	38 639	49 927	-55 090	-202 475	17 181	-30 702
Rate of negative profit	10%	13%	9%	35%	90%	27%	50%
Collapse rate	0%	13%	5%	0%	0%	9%	8%
	Origin of experience						
parent/family	20%	38%	27%	41%	0%	0%	0%
training	10%	25%	91%	71%	10%	0%	0%
self experience	60%	88%	100%	71%	100%	100%	100%
other	50%	13%	9%	6%	10%	9%	0%

Tables 65 to **70** offers a similar presentation of economic results to compare the different technical systems in each of the villages surveyed.

Table 65. Economic comparative analysis of production systems: Ly Hoa Hiep village.

Ly Hoa Hiep (Cangio)	Extensive	Extensive + Dry crop	One year operation
Pond area (ha)	3	10,3	8,5
Stocking density (1.000 fry/ha)	-	2,6	-
Echeloned stocking (number)	-	1	-
Production (kg/ha)	76,7	73,6	74,4
Technical efficiency (kg/1.000 fry)	-	2,7	-
Survival rate	-	10%	-
Price (Dông/kg)	30 000	100 000	90 000
Total cost (Dg/kg)	761	59 794	51 361
Benefit (Dg/kg)	29 239	40 206	38 639
Rate of negative profit	50%	0%	13%
Collapse rate	50%	0%	13%
Number of farms	2	6	8

Table 66. Economic comparative analysis of production systems: Ta Ank Huong.

Ta Ank Huong (Ca Mau)	Extensive + Dry crop	One year operation
Pond area (ha)	1,1	1,1
Stocking density (1.000 fry/ha)	2,4	2,4
Echeloned stocking (number)	1	1
Production (kg/ha)	116,5	116,5
Technical efficiency (kg/1.000 fry)	6,2	6,2
Survival rate	18%	18%
Price (Dông/kg)	86 500	86 500
Total cost (Dg/kg)	69 319	69 319
Benefit (Dg/kg)	17 181	17 181
Rate of negative profit	27%	27%
Collapse rate	9%	9%
Number of farms	11	11

Table 67. Economic comparative analysis of production systems: Ap Tac Nam Can.

Ap Tac Nam Can (Ca Mau)	Extensive + Dry crop	Extensive + rainy crop	One year operation
Pond area (ha)	1,8	1,8	1,8
Stocking density (1.000 fry/ha)	2,1	2,4	-
Echeloned stocking (number)	1,7	2,2	-
Production (kg/ha)	50,5	30,1	80,6
Technical efficiency (kg/1.000 fry)	2,6	1,6	-
Survival rate	5%	3%	-
Price (Dông/kg)	121 111	116 667	121 111
Total cost (Dg/kg)	75 667	153 861	151 813
Benefit (Dg/kg)	45 444	-37 195	-30 702
Rate of negative profit	42%	67%	50%
Collapse rate	25%	42%	8%
Number of farms	12	12	12

Table 68. Economic comparative analysis of production systems: Long Toan village.

Long Toan (Tra Vinh)	Extensive + dry crop	natural shrimp	One year operation
Pond area (ha)	0,17	0,16	0,17
Stocking density (1.000 fry/ha)	4,1	-	-
Echeloned stocking (number)	1	-	-
Production (kg/ha)	969,8	170,0	1023,9
Technical efficiency (kg/1.000 fry)	23,6	-	-
Survival rate	54%	-	-
Price (Dông/kg)	89 381	21 190	86 496
Total cost (Dg/kg)	38 709	-	36 569
Benefit (Dg/kg)	50 672	-	49 927
Rate of negative profit	9%	0%	9%
Collapse rate	5%	0%	5%
number of farms	22	7	22

Table 69. Economic comparative analysis of production systems: Thoi Thuan - Thanh Phuoc villages.

Thoi Thuan - Thanh Phuoc (Ben Tre)	Extensive + dry crop	natural shrimp	Extensive + rainy crop	One year operation
Pond area (ha)	4,1	5,2		4,1
Stocking density (1.000 fry/ha)	4,1	-		-
Echeloned stocking (number)	3,6	-		-
Production (kg/ha)	237,2	66,1		362,3
Technical efficiency (kg/1.000 fry)	6,6	-		-
Survival rate	17%	-	No	-
Price (Dông/kg)	96 429	22 037		73 465
Total cost (Dg/kg)	100 793	-	Signifiant	128 556
Benefit (Dg/kg)	-4 365	-		-55 090
Rate of negative profit	41%	0%		35%
Collapse rate	0%	0%		0%
Number of farms	16	8		16

Table 70. Economic comparative analysis of production systems: Ving Ting village.

Ving Ting (Bac Lieu)	Extensive	Extensive + Dry crop	One year operation
Pond area (ha)	16,55	16,4	16,6
Stocking density (1.000 fry/ha)	-	1,4	-
Echeloned stocking (number)	-	1	-
Production (kg/ha)	82,6	17,1	94,6
Technical efficiency (kg/1.000 fry)	-	1,7	-
Survival rate	-	4%	-
Price (Dông/kg)	12 690	75 000	15 026
Total cost (Dg/kg)	45 354	33 255	217 501
Benefit (Dg/kg)	-32 688	41 745	-202 475
Rate of negative profit	100%	86%	90%
Collapse rate	0%	86%	0%
Number of farms	3	7	10

This confirms the results that there are large differences with high positive results in some cases and very high losses in over. These data must be interpreted with precaution. Some are to be taken with caution because of the conditions of collect and other should be interpreted regarding the specific local conditions. The reader should refer to the reference text presenting the results of the survey to get a better view of the limits of these results.

One hypothesis to explain the big differences observed is that many of the surveyed farms are located far inshore. Plotting the two variables, productivity and distance from the shore, give an indication of the pattern that such a model would take (**figure 81**). But the number of cases contradicting the hypothesis is not negligible in the sample. Therefore further investigation seems necessary before such a relation can be estimated.

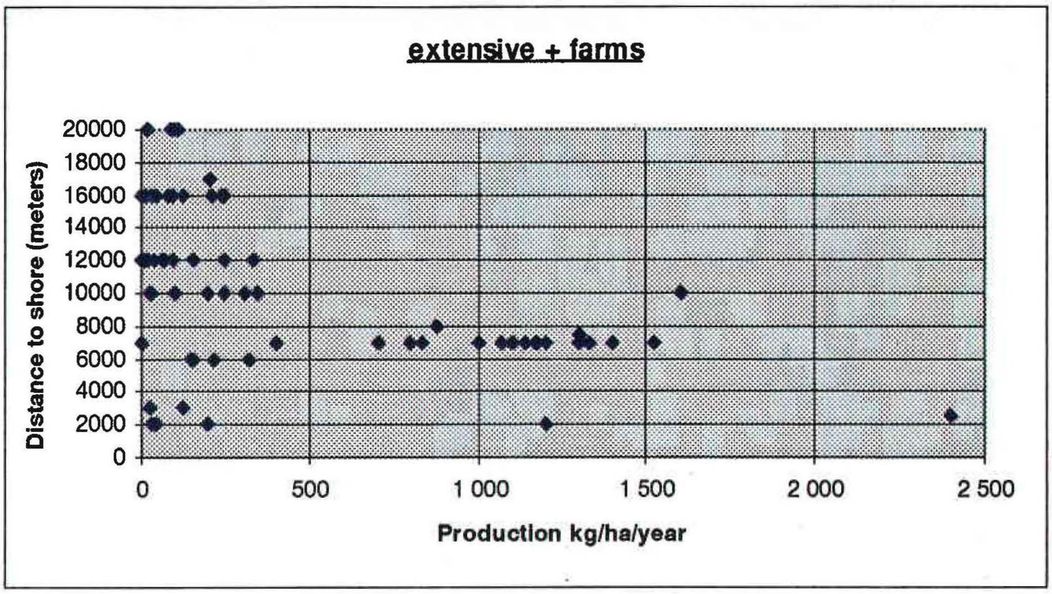


Figure 81. Correlation between production and distance to shore - extensive + farms.

Farmers have been asked to identify the main difficulties they have encountered in the recent years (**figure 82**). With the exception of marketing and land control, most other sources of problem like environmental problems, diseases, lack of access to capital, quality of fry are encountered by 30 to 50 % of these farmers. But surprisingly more than 80 % are confident in the future of shrimp farming (**figure 83**). The evidence of comparatively significant returns from shrimp production and the public incentives for the development of shrimp farming may explain this optimism.

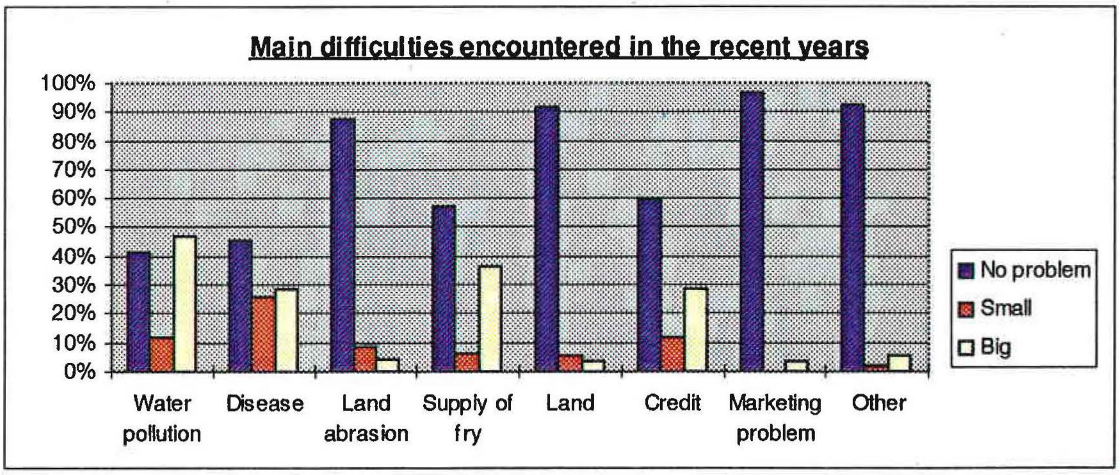


Figure 82.

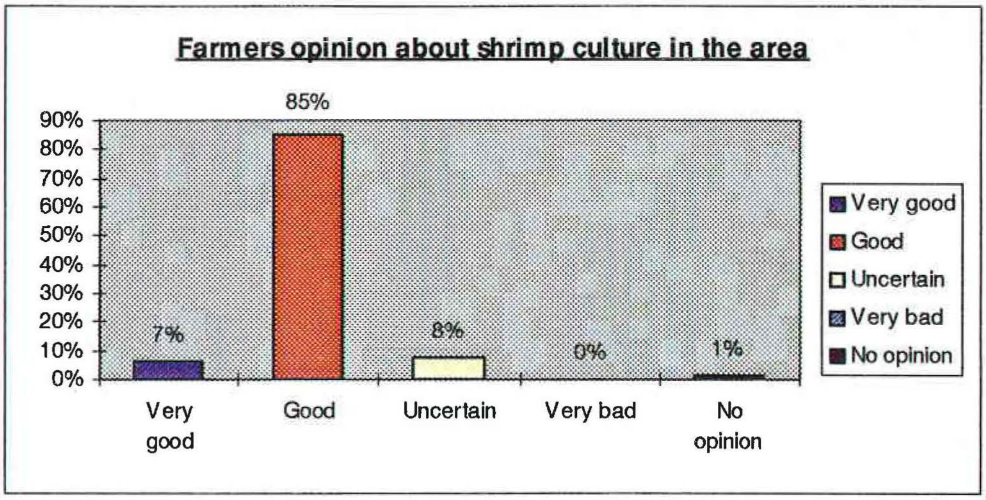


Figure 83. Farmers opinion about shrimp culture in the area.

3.4. Discussion

From the results of the two case-studies here, it clearly appears that collective action has two major dimensions. One is technical and the other is environmental. Designing technical practices that will ensure a good control of production outcome variability seems essential in the context of low levels of intensification. They are proved to bear significant returns to local economies, higher than any other primary production, but also to be very risky. The lack of control over the technical process and the lack of a clear definition, and probably understanding, of the major determinants of this variability calls for a public investment in applied research, transfer and training. Most of this is at present offered by the main feed companies who promote their products by providing advices and training in a very uncontrolled way. To provide clear guidelines and convince farmers of the risk of not following them would solve a large part of the problem resulting for stocking and feeding rates higher than the pond design and management would normally allow. Beyond the information problem it is also a matter of incentives for the farms to regroup themselves and act collectively in this direction.

The second problem, qualified as environmental, concerns the collective management of the coastal waters as a complex system of links among various components. They are the water resources, fresh, brackish or salted, surface of ground, that are used to rear shrimp including the water in the ponds. They are part of more or less connected ecosystems, marine and on land. It should be considered as a management unit to which some form of collective/public action should be applied. The coastal ecological systems must be defined in relation with the scope of public policy objective. The strongest relation to be found among compartments or ecosystems should be used to define the border of the coastal ecological systems that may be considered either for analysis, management, public choice definition and evaluation, or modelling. Defining the border of an ecological system for management purpose relates both to objective and subjective criteria. Physical (geographical) limits may be self designating in the case of a closed or semi-closed bay. The pond area connected to this marine ecosystem may also be clearly defined. Very distant relation through river system are out of the coastal ecological system, but not local fresh or brackishwater resources. The collapse of Taiwanese products has shown the important role that ground water can play for the sustainability of shrimp products. The definition of coastal ecological system, and the importance of the water component in its definition, is linked the notion of carrying capacity. For a given technology how may hectares of pond can be developed without threatening the major equilibrium of the ecosystem. It is more likely that a progressive precautionary approach supported by well designed follow-up action will be more appropriate than a normative modelling approach.

The first target for collective action in the area of environment can be to improve the conditions of shrimp rearing in each farm by providing quantitatively and qualitatively good water. The management of water supply, except the few cases of sole ownership (almost unique user) over the coastal water system, is typically a matter of collective action. Through the management of water in-coming and pond out-going water, it clearly appears that the pond management have an external dimension that relates directly to collective choices by group of farmers with eventually the support of public action. Building properly designed canal, to the size of the need for water, discriminating among what part of this cost should be bared by private farmers and which part may be justified as a public investment, is an evident part of it. Imposing, by administrated norms or by economic incentives, limitation of the waste disposal in the ecosystem so that in-coming water quality is not degraded by waste from the ponds is much more difficult to implement. The relation between the total waste disposed from the ponds in the ecosystem and the productivity of rearing or the out break of disease is not easy to understand except few cases of chemical pollution. Externalities out of the industry, i.e. beyond the interactions among the shrimp farms only, are another important area of concern it some places. The coastal waters concentrate all the pollution flows from the surface and ground water system in its watershed. The farm efficiency largely rely on the fact that coastal waters are free of any harmful substance to the shrimp and meet minimum physico-chemical and bacteriological characteristic required by shrimp farming. This groups of phenomenon must be considered the impact of up-stream industries on coastal waters quality.

3.5. Conclusion

From the two case-studies it is obvious that the sustainability of shrimp farming is much threaten both in terms of guaranteeing long lasting flows of positive returns to investors and local economy but also in terms of finding an acceptable balance with environmental assets, namely the coastal ecosystem (fresh, brackishwater and sea water resources, mangroves, biodiversity). Most of the threat comes from the development of the industry itself but the environmental threat put by other industries and urbanisation on shrimp aquaculture should not be neglected. Whatever the level of intensification is, shrimp farming is a major source of returns thus attracting the interest of many people. This strong economic incentive is supported by the fact that shrimps are produced for export on world markets that are still under expansion. As long as the emergence of new significant production goes with the collapse of major production areas, the world references prices are not threaten. But this is a variable far from the control of producers or regional policy-makers. Another factor is that environmental resources are consider as very low value assets in economies facing the difficulties of economic development and even high levels of poverty like in the Mekong delta. Thus the public concern over natural resources doesn't provide incentive for a collective action that would balance private economic incentive. Furthermore the relatively low level of industry collective organisation and the low capacity of public authorities to set and implement a management policy. Considering these dynamic forces and limitations a profile of "fast growth and collapse" is more likely to be dominant for many years in shrimp farming and sustainability issue will long be the core question of shrimp farming development in regions like Lampung province or the Mekong delta. The records of other countries or even other regions in Indonesia tell us that it is a very complex question and that one should remain very careful when examining it. There is no room for normative prescriptions or definitive conclusions.

Lampung province is an example of very fast growth in a very promising economic context. The diversity of natural conditions has been used to develop a very diversified industry in terms of investment strategy and technical options. Both evidence of high returns and signs of difficulties are found in a Province that hosts among the biggest projects in the world. Those are large private investment that could be considered of no relevance to public policy if there was not thousand of persons concerned by the potential rapid collapse of shrimp culture. The need to design some frame for public action is well recognised by the actors but the capacity to implement it is low today. To improve this capacity, one output of this project has been to propose a methodology to create and manage a socio-economic database that would help to design public-policy. But this cannot really be usefully if the general condition of defining and implementing public policy for shrimp management is not improved. This is discussed in the next chapter.

For the Mekong delta, the situation is much more difficult and all the results show that the potential for shrimp farming development is heavily constrained. Both environmental conditions and the diffusion of know-how play against the intensification of the production even at very low levels. Still the conclusion cannot be completely negative. First because there is an evidence of significant economic returns, although technical ratio are low, in a region where alternative opportunities for capital investment and labour employment are very limited. Secondly the industry represents a big volume of production and a significant source of foreign currencies for the country. The socio-economic research has been too limited to provide more than a very general feeling but it clearly appears that the objectives and means of development policy should be rapidly and deeply reviewed. The intensification is probably not the priority excepted in few cases and should be left to private initiative. Intensive training and extension should be rapidly develop with a programme to experiment and transfer technical system adapted to the condition of the delta. This may include pond design and pond management, product handling, PL and feed supply, range of species used for farming.

For further research in socio-economic the main recommendation is that three approaches should be more in-depth investigated. The first is the analytical approach of pond ecosystem management and its link with economic performance as explained in the introduction of chapter 1, task 3. The second is to provide some expertise to help implementing follow-up tools such as socio-economic database that cannot be disconnected from bio-technical information. The third is to investigate in more details the regulatory and economic means that can be used as incentives to reconcile the objectives of sustainable development and the potential for economic returns on a long term basis. In all cases only a multidisciplinary approach can yield positive contribution to the understanding of the difficulties to ensure shrimp farming sustainability.

Task 4: Remote sensing as helping tool for diagnosis

Authors: *J. Populus* *Ifremer/DEL/AO*
A. Wibowo *BPPT*
Mr Bambang Sumartono *BADC*
Mrs Woro Hastuti *BADC*

4.1. Introduction

As time flies, remote sensing has come from an early age to the time of some maturity. Once a research tool for closed circles, it is now more and more looked at as an operational mapping tool. The nature of, and access to images, together with rapid progress in techniques and equipment, makes it widely available to developing countries. These countries regard it not as something out of reach for them, but as a tool they are able to master for rapid access to information. As an evidence, Spot and Landsat images are widely used in many development projects in Indonesia. In a recent assessment, around forty facilities were identified over the country, with a majority in the capital Jakarta.

In this project, we are looking at two different kinds of remote sensing tools. Satellite images of course are the data easiest to acquire, both in terms of cost and operationality. A discussion is given herebelow about what can be expected in the domain of coastal waters mapping, whereas land use mapping has become a classical output of such imagery.

The acquisition of airborne hyperspectral data was also organized within the project, with the idea that the increased spectral capability of the instrument used (the Casi or Compact Airborne Spectrographic Imager) will reveal more of the water quality and allow correlations with field samples. Another airborne technique is the classical professionnal aerial photography, which does not require a complex digital tool such as the Casi unavailable in the country. It is for sure less costly than digital techniques but suffers from the same constraints of weather and clearance and is not so effective over coastal waters. Although it has not been tested however in this project, it should not be lost from mind.

4.2. Methodologies, materials and methods

4.2.1. Bibliographic elements

The bibliographic study has concerned the current status of a) coastal water quality studies, b) the feasibility of running airborne data acquisition campaigns.

4.2.1.1. <u>Remote sensing of water quality</u>

Remote sensing provides good insight into a given ecosystem and helps compensate for the current lack of geographical information. On one hand, with the help of limited field investigation, « static » information, i.e. the land use of a given area is easily visualised. On the other hand, when it comes to investigating more « dynamic » coastal waters, although it does not replace water sampling, « remote sampling » may give a gross estimate of the water content (or rather, indicate water type).

Two types of methods are used in remote sensing of sea water: a) physical, establishing a model of the light optical path from the sun to the target and then to the sensor, b) empirical by relating sensor values to field values. Modelling the interaction of light with the water is quite complex due to the intricate response of its various constituents. As has been shown by a few authors (Dekker *et al.*, 1994), only a large number of spectral bands would enable an approximation of the spectral curve of turbid coastal waters, generally referred to as « case 2 waters », that is containing varying amounts of suspended sediments, chlorophyll and organic matter. This implies field collection of various types of coastal waters and entensive laboratory work on their optical properties. A lot of knowledge is still lacking, which prevents working in an analytical way.

Current high resolution satellite images fall quite short of these spectral requirements, having only three wide spectral bands with limited sensitivity to subtle variations in the water resulting radiance. Empirical relations are usually sufficient to describe a given situation. They are based on simultaneous acquisition of remote and field data, which is practically impossible to carry out, unless airborne techniques are used.

Dekker (1994) reviewed the methods used for retrieval of inland water parameters. He recognized that permanent variations in irradiance, atmosphere, water surface and composition make empirical algorithms valid only for a given situation where remote sensing data are acquired simultaneously to *in situ* data in sufficient amounts to be statistically representative. This is all the more true in coastal waters, even more subject to these variations.

If satellite data are utilized, only restricted investigation is possible. However within the three to four available channels of the current mapping satellites (i.e. Spot and Landsat), some progress still seems possible in terms of empirical relations for water quality, by additionnaly using the near-infrared channel. Various authors (Nichol 1993, Ekstrand 1992, Tassan 1993) have used Landsat Thematic Mapper data to map the quality of water surfaces affected by terrestrial inputs in the coastal zone. They have successfully applied regression techniques involving various combinations of these four bands to retrieve such parameters as chlorophyll and suspended sediments.

4.2.1.2. Feasibility of acquiring digital airborne imagery

At the same time as satellite data are permanently improving, with announced resolutions of 10 metres and probably 5 metres within the next few years, there is an increasing demand for airborne solutions, under several forms.

Firstly, conventional air photo is doing a come back, as scanning power and computer processing capability increase. It so happens that high quality air photo, acquired for mapping purposes by the military as well as the civil sector, is more widely made available to other uses. Comparable in its content, if not in its geometry, amateur oblique air photo may also be scanned (as desktop scanners become currently available) and interpreted, yet with some registration difficulties. Of course, not much effort has so far been devoted to geo-referencing and calibrating such data (King, 1995), but such techniques will increase in importance as their applicability increases and their implementation cost decreases. By all means, scanned air photo offers the highest definition.

Secondly, going into multispectral airborne video and digital camera sensors is quite an exciting challenge. Their advantage is the access to more channels, with higher sensitivity and the promise of more in-depth interpretation. However, some authors (King and Vlcek, 1990) showed the dimensionality (number of bands required to contribute to 95 % of the variance in principal component analysis) of various land cover types to be equal to five, with a lot of correlation between bands adjacent to the major five. It is worth noting that the addition of a thermal infrared band, when the technology allows it, will be a major advance.

However, a main limitation will still restrict the use of airborne digital imagery, that is the small view angle which does not allow mapping large areas in a cost-effective way. The usual figure for across-track frame size is 512 elements (bound to be increased to 1024). This means that if a 5 metre resolution is wanted, the swath remains limited to 2.5 km.

Whatever the instrument embarked, airborne acquisition will always suffer from two well-known drawbacks, the weather and institutional hazards. The former affect all regions in the world, but mostly tropical and equatorial ones. In some countries Air Forces regulations are still strong and clearance difficult to get, which may threaten campaign completion.

4.2.2. Satellite imagery acquisition and processing

Two satellite images were purchased during the project, one Spot image and one Landsat images. A Landsat image acquired during the former AADCP project was also used. Both types of images are basically the same in their capability for thematic mapping, i.e. the extraction of features present at the earth's surface. Let us just say that their pixel size is a bit different (20 metres on Spot and 30 metres on Landsat), which gives a little advantage to Spot, especially when we are concerned with the identification of geometric structures such as aquaculture ponds with a small dimension approaching pixel size.

The scene size is also different, 200*200 km^2 for Landsat, which in theory would allow one scene to catch the whole Lampung province at once. Unfortunately the rigid Lansdat assemblage scheme makes the province fall at the crossroads of four scenes. On the contrary, Spot only has 60*60 km^2, but the position of the scene may be chosen at the user's choice, thanks to satellite programming.

These advantages have to be balanced in any given situation. Another point of importance is the wealth of the archive, which may provide older but better quality data, especially when change studies are wanted. Finally, clouds are a common hindrance, as will be seen in the 1995 Spot image.

Typically, delivery times are of less than 2 weeks for a Spot image, a very good figure which shows the operationality of the system, both commercially and technically. Conversely, ordering Landsat data is a painful process, as this community is far less organized towards efficiency. This also depends which receiving station is concerned. Typically, a delay of up to two or three months is common before getting the data.

Table 71 below recapitulates the images utilised in the project. October 1991 Landsat TM image was used as the reference image of the area, mostly to show land use at the time, and more specifically the extent of the aquaculture activity. The June 1995 Spot image, with its finer resolution, was exploited for several purposes, as is described below. The choice of this image was difficult. The whole series of images spanning a two year period was cloudy. The advantage was given to an image cloudfree along the coastline, even though its upland part is worthless. Although limited clouds are present over « Coco bay », the Indian Ocean site, farms remain visible.

The August 1996 Landsat image was initially intended to illustrate the northern sites of the Lampung province and their influence on the southern zone, although it has actually not been processed in this study.

Table 71. Satellite images used in the STD3 project.

Image	TM	SPOT	TM
Date	Oct. 7, 1991	Jun. 26, 1995	Aug 1, 1996
Season	dry	dry	dry

4.2.2.1. Atmospheric correction

The first processing step was to calibrate the images and apply an atmospheric correction in order to transform the digital counts delivered on the magnetic tape into true ground reflectance. This operation is mandatory if several situations are to be compared or if an analytical formula is applied. It means a) transforming the values into at-sensor radiances using calibration coefficients provided with the image, b) correcting for the optical path of the atmosphere to express ground reflectance, as would be measured with a field radiometer.

This second operation is performed with the « 5S » software (Tanré, 1988) which allows users either to build their own atmospheric model if they have the data for it, or utilize one provided by the software and based on typical values of atmospheric contents. In its simplest form, the only inputs to the model are a) the horizontal visibility, which can be obtained from the local weather station at acquisition time and is used to infer an approximate aerosol content, b) the sun elevation. The software then runs the correction using coefficients issued from 5S. For each scene, the correction is applied to the study sub-area and also to a patch of what is referred to as « clear water », i.e. offshore water supposed to be free from terrestrial influences and hence representing typical Java Sea water.

In order to check the quality of the correction, « clear water » values were computed for various scenes over the Java coastal zone, the consistence of which had been shown before (Populus *et al.* 1995).

4.2.2.2. Geometric corrections

The processing was performed using Erdas Imagine and Arc/Info. The processing was not performed for the whole Spot scene which covered almost the whole of the Lampung province, but only for an area along on its east coast in Labuhan Maringgai. A subset of image size 1010 pixel x 3179 pixel (20 km x 63 km) was created for land cover processing.

Even though the Spot image was delivered on level 2A, i.e. georeferenced to the UTM coordinates systems, further registration was still needed in order to integrate it with base maps, i.e. topographic maps on scale 1/50.000. A mere shift in X and Y was sufficient to ensure registration. The shift value was obtained by picking conspicuous points on the Spot image and on the topographic maps (for instance road crossings) and computing the shift to apply to the image.

4.2.3. Airborne imagery acquisition and processing

The idea to run experimental airborne imagery acquisition stems from two considerations:

a) the geometric ones recognizes that satellite spatial resolution is still too coarse to allow mapping of objects such as aquaculture ponds with a dimension on the order of 20 metres,

b) the radiometric one foresees that the increased spectral capability of an airborne sensor such as Casi may provide an insight into more detailed pond features.

4.2.3.1. Airborne acquisition campaign

The period chosen for the campaign was the second half of May, when the dry season is supposed to have settled for more than one month. At this time of the year, not far from the winter solstice, the sun elevation reaches no more than 70° at noon. However, one can see that with a sensor field of view of 40°, we are close to the specular reflection situation. In order to keep away from it, it is advisable not to operate between 11 AM and 1 PM. Several flight lines were to be run on each site, three over Merak Belantung for a resulting mosaïc width of 4 km with 50 % overlap, and four over Labuhan Maringgai for a width of 5 km. Another individual flight line was planned in Labuhan Maringgai extending 15 km offshore perpendicular to the coast. All flight lines had to be run away from the sun, i.e. heading South.

According to past experiences, coincidence between an airborne campaign and associated field work is effective in one case out of five. This is all the more an acute problem in the coastal zone where water dynamics make field measurements very ephemeral. As weather hazards often induce flight postponement, the management of field teams is a real problem. It is often impossible to maintain for a few days a task force of people and equipment in such adverse environments as tidal flats for instance. VHF radio communication often fails between the aircraft and field teams. This is even worse when the airfield is far for the sites, as was the case in Lampung.

Field work is described in the hydrobiology section of this report. As a support to the airborne campaign, it consisted of two transects for water sampling, with particular emphasis on recording accurate station locations, as well as the investigation of two farms showing various stages of pond water quality.

As was stated in the September 1995 progress report, only two Casi flight lines were really exploitable, i.e. line 1 (acquired May 22) extending offshore from the town of Labuhan Meringgai on a distance of approximately 15 km, and line 2 (acquired May 24) running alongshore from 2 km South to 3 km North of the same town. The two images are shown on **figure 84**. The very limited extent of line 2 was unfortunately due to a late acquisition start time in the north, and also to clouds lying in the south. The images contain 12 channels, of which only three are selected for the false colour composites of the figure. The bandset appears on **table 72**.

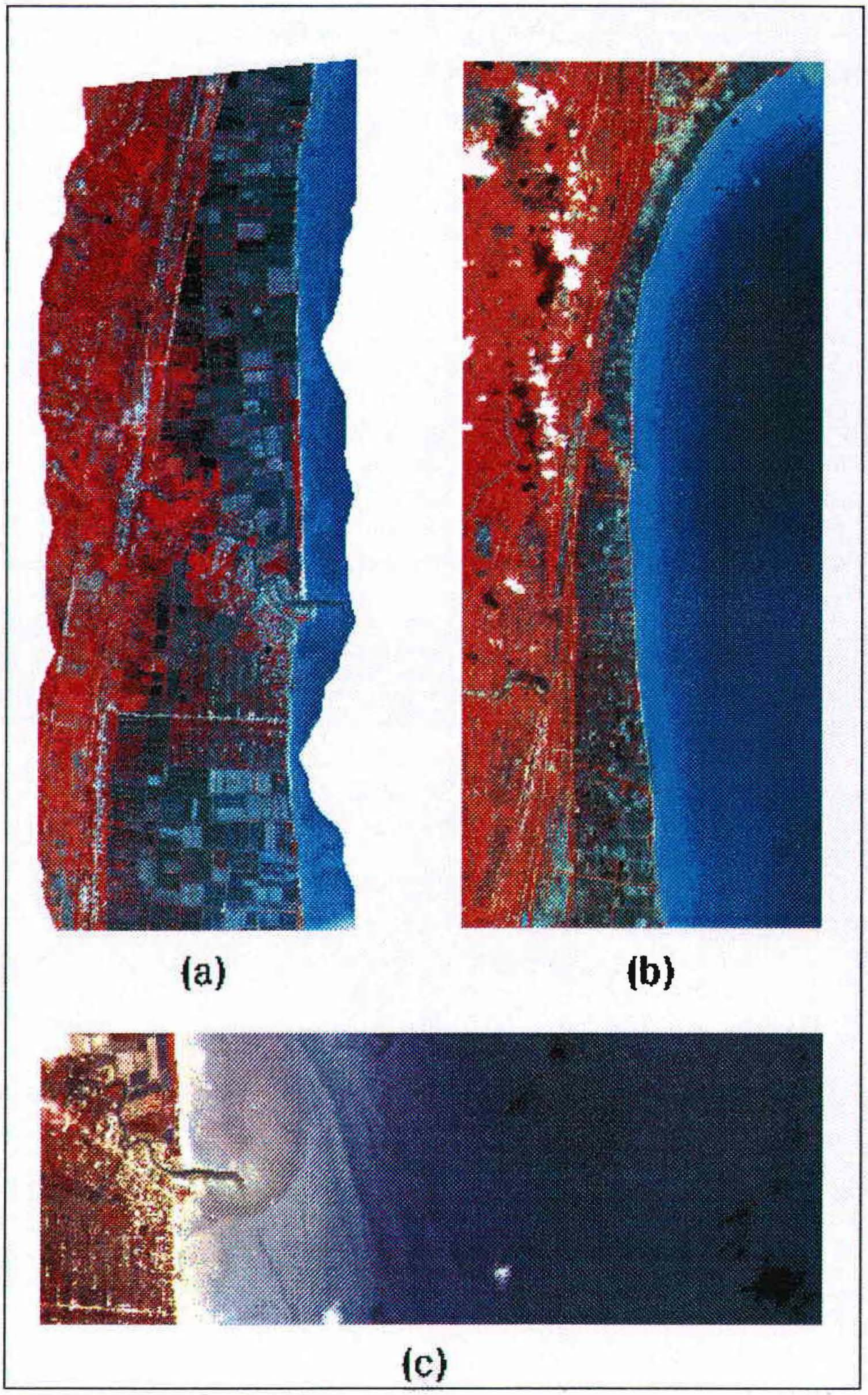


Figure 84. (a) Casi alongshore flightline over ponds, May 23 1995,
(b) Spot image subset June 26 1995,
(c) Casi offshore flightline, May 22 1995.

4.2.3.2. Radiometric corrections

Image files were delivered at the end of July 1995 on exabyte tapes in a format that could be right away imported into our image processing facility (Erdas Imagine software). Similarly to satellite imagery, the signal at the plane is a radiance generated by the target and recorded after upwelling through the atmosphere. In order to get a ground reflectance, the radiance has been corrected with the 5S model which solved the atmospherical content for each altitude and inversed the measured radiance to a ground radiance. It also evaluated the sun irradiance on the ground and hence yielded the true ground reflectance. The only unknown was the aerosol content. As no data was available from coastal stations or airports, the horizontal visibility was arbitrarily taken as 10 km, a current value.

As an example, typical radiance values recorded by the Casi range from 0.5 to 15 mWatts/cm2/st/µm with a quantization step of 0.001 mWatt, which denotes an extremely high instrumental sensitivity.

4.2.3.3. Geometric corrections

Difficulties in mastering the geometrical quality of airborne images have hampered their development for a long time. In the particular case of a push-broom instrument such as Casi, the line mode acquisition, as opposed to the matrix mode of air photography requires a line-based correction for plane attitude. It is performed by a gyroscope that measures both roll and pitch used later for image processing. Besides plane attitude, the positional data is given by GPS (Global Positioning System). Although ordinary GPS gives an absolute accuracy of 100 metres, the incursion of its error curve is quite slow, which makes it proper for mapping work. As was done with the Spot image in relation to the topographic map, Casi images here have been simply shifted by using a ground control point and made to fit with the Spot image.

Nota: another reason for properly mastering the geometry is the narrow swath of the sensors (2.5 km here for a 4 metre pixel at an altitude of 2500 metres). If one was willing to have a wider ground coverage, splicing several contiguous fligh lines would be necessary. In order to mosaïc without any ground reference, the best technique is differential GPS. The positional accuracy is then a function of the distance between the sensor and the reference station emitting from a geodetic point. Typically absolute accuracy varies between 0.5 and 5 metres for a distance between 20 and 100 km. In our particular case, no differential GPS could be used, as this would have implied even more logistical problems, i.e. keeping a technician in standby with the device.

4.2.3.4. Aiborne data quality assessment

The two offshore lines in Merak Belantung and Labuhan Meringgai were exploitable, even though scattered clouds made it difficult to run a rectilinear transect. The three alongshore lines in Labuhan Meringgai, initially bound to be mosaïcked, were in a very bad shape and only exhibited parts of the ground below. This was due to problems in navigation, severe plane movements due to overcast weather, clouds and their shadows masking the ground.

Whatever the very limited data amounts, the available data is of rather acceptable quality, both radiometric and geometric. High frequency distortions are hardly visible in spite of jerky movements caused all along the flights by unstable atmosphere. Low frequency distortions were shown by the winding aspect of the rectified images. This testified that the gyroscope did a good job.

When evaluating the quality of the geo-referencing, there is a slow drift between the Casi coastline and that of Spot. This is due to the use of ordinary GPS (see above). In order to get a perfect fit, warping would have been necessary, i.e. running a polynomial with GCP's in order to resample the Casi image to fit the Spot image.

Comparison of true radiance values on both types of imagery

The spectral bandset is shown in **table 72**. We had no previous experience of how to choose the best bandset for water studies. 12 spectral bands were selected according to the literature and especially works by Dekker who designed a specific bandset for inland waters. These were confronted with those of the Seawifs satellite sensor for ocean colour. Three bands were also selected in the near-infrared range in order to address both the terrestrial vegetation and the very coastal fringe of water.

As a result of atmospheric corrections, both satellite image radiance values (Spot or Landsat TM) and airborne (Casi) were turned into reflectance values, an intrinsic variable of ground objects (**table 73**). In order to check the consistency of the correction, reflectances of identical targets in the corresponding channels have been compared:

Casi #3 (green: 0.555-0.575 nm) and Spot XS1 (0.500-0.590),
Casi #6 (red: 0.643-0.654) and Spot XS2 (0.610-0.680),
Casi #12 (infrared: 0.840-0.856) and Spot XS3 (0.790-0.890).

Table 72. Casi spectral bandset for the Lampung campaign.

Band #	Begin nm	End nm	Spectral Colour
1	485	505	green
2	510	529	green
3	556	575	yellow
4	590	611	orange
5	620	630	red
6	643	654	red
7	661	670	red
8	671	686	red
9	687	696	red
10	702	713	red edge
11	745	752	infrared
12	840	856	infrared

Table 73. Comparison of Spot and Casi reflectances.

	XS 1	XS 2	XS 3	CASI 3	CASI 6	CASI 12
Dune vegetation	0.09	0.07	0.28	0.10	0.06	0.40
Bare Soil	0.14	0.16	0.20	0.18	0.22	0.23
Empty pond	0.15	0.16	0.19	0.15	0.15	0.19
Sand	0.20	0.23	0.25	0.18	0.37	0.43
Full Pond	0.06	0.06	0.05	0.08	0.07	0.06
Orchard vegetation	0.08	0.06	0.37	0.10	0.06	0.56
Offshore water	0.07	0.02	0.006	0.08	0.04	0.009

The Casi seemed to systematically enhance infra-red values (Casi 12), especially for high reflectances. The agreement was generally good in the other two channels. On sand, while Spot's three channels exhibit even reflectances, Casi 6 and 12 were way off. This was probably due to an inconsistency in the selected targets. While Spot, averaging 25 Casi pixels, levels off any spiky pixel, the choice of the Casi « pure pixel » is quite critical.

4.3. Results of remote sensing for monitoring aquaculture

4.3.1. Coastal zone mapping

4.3.1.1. Land cover mapping

Concerning landcover, the latest work dates back to the land cover maps established during a former project with a 1991 landsat TM scene. It is proposed that this situation be updated using a 1995 Spot scene. The work emphasizes the coastal zone and changes from paddy culture to shrimp pond culture and also tries to apprehend coastal erosion trends.

The method used for land cover classification is supervised classification with training area based on ground checks. There were 5 sets of training areas representing land cover classes as follows:

- aquaculture ponds including intensive, semi-intensive and traditional
- dense vegetation, including forest, homestead gardens and other dense vegetation
- low dense vegetation with paddy culture and grass
- mangrove. This category may get mis-interpreted with low dense vegetation class but its location at the sea-front makes it easily identifiable
- water bodies, including rivers and the sea.

This land cover classification will be used to assess land cover changes during the 1991 to 1995 period, focused on paddy culture conversion and coastal erosion. The land cover maps already available from previous study (AADCP 1991) had the classes: aquaculture pond, homestead garden, mixed garden, paddy culture, shrubs, water bodies.

Based on 1991 and 1995 land cover maps, it is shown that there has been dramatic conversions of paddy field to pond culture. These changes occur in all of the study area, amounting to about 1238 hectares of newly created ponds. **Table 74** shows that the greatest change has occurred in Karya Tani (see the map on **figure 97**, chapter 2, paragraph 2.2.4), where 79 % of to-day's ponds have been created in the last five years. High ratios have also been found in Srimino Sari, Pasir Sakti and Muara Gading Mas. Out of an overall surface of 3629 hectares in 1995, one third had been gained from paddy in four years.

Paddy to pond conversion ratios illustrate one type of intensification, i.e. surface intensification. In a traditional farming environment, this will result in a linear increase in production. When combined to rearing intensification (i.e. higher animal density), increase in production becomes more dramatic. These aspects will be discussed in more details in chapter 2, paragraph 2.2.4.

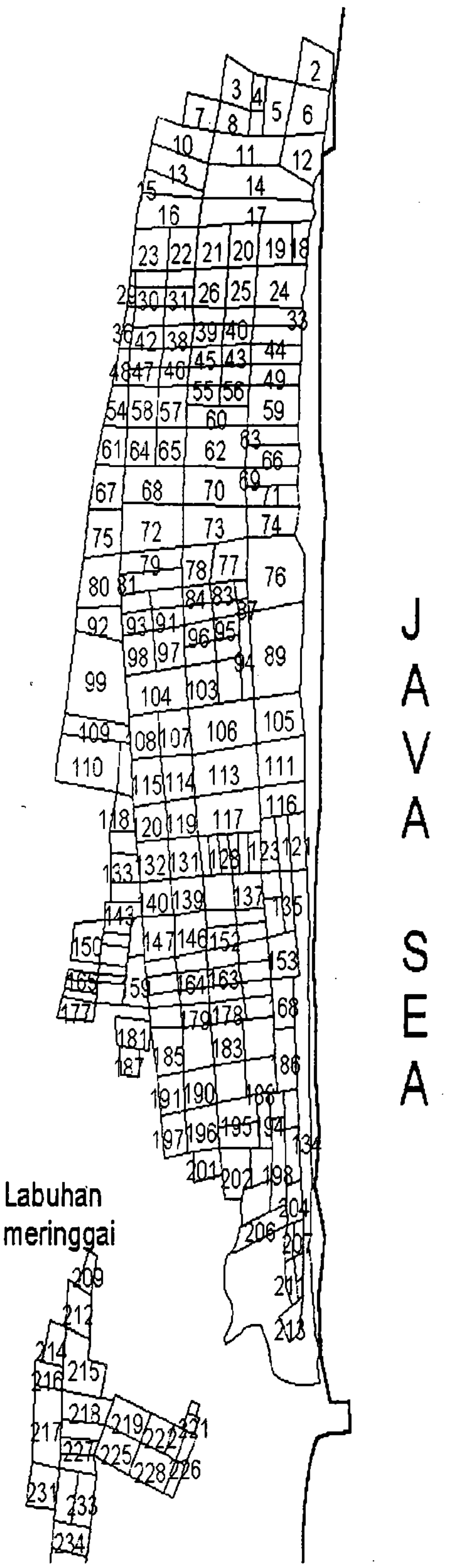
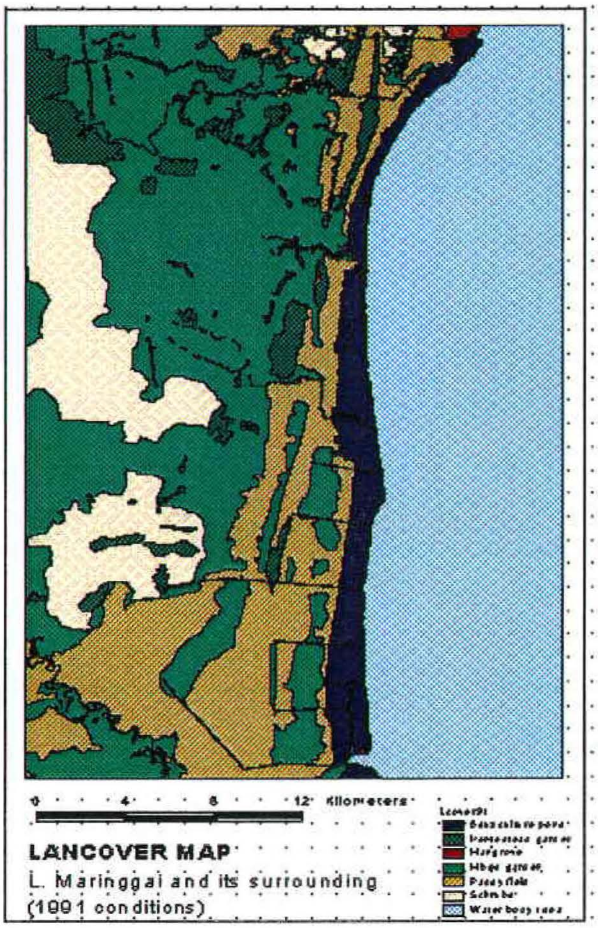


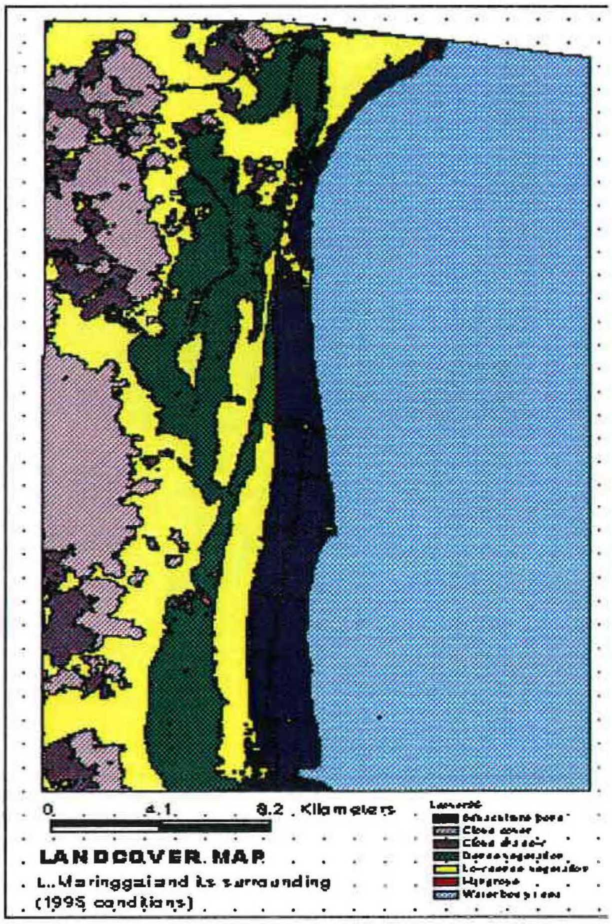
Figure 85. Pond cadastre around the town of Muara Gading Mas, as derived from Casi imagery. Aprox. scale 1/12000.

4.3.1.3. Mangrove and erosion monitoring

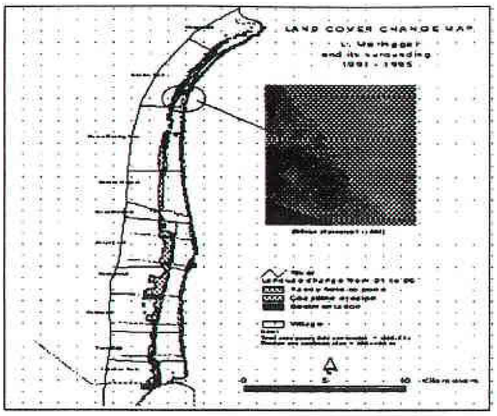
Mangrove mapping using Spot and Landsat images has proven to be feasible. Along the Eastern coast of the Lampung province, mangrove has mostly been eradicated as aquaculture reclaimed more and more land of the coastal fringe. We can see on the Spot image that mangrove along the Labuhan Maringgai coast is either very limited (less than 10 metre thick, leaving a fine reddish streak) or has been totally cut down. However, some areas which have mangrove patches big enough can be detected, as seen in Margasari **(figure 86 a & b)**.

These conditions make mangrove mapping difficult due to the size of mangrove rather that because of the spatial resolution of the Spot image. In the North, where whole mangrove stands have remained, they could easily be detected and inventoried.





(a) (b)



(c)

Figure 86. (a) and (b) land use changes, (c) erosion trend over the period 1991-1995 in the Labuhan Meringgai area.

Coastal erosion can also be easily mapped by satellite image. Between 1991 and 1995, the East coast of Lampung has undergone severe coastal erosion. The results show that in places, the coastline have been shifted of about 200 to 400 meters from its original position. Sriminosari is the area which most suffered from coastal erosion. In Karya Tani the problem is reversed, with sedimentation occurring (**figure 86c**).

4.3.2. Water quality assessment

4.3.2.1. Application of the TSM model to the Lampung coast

It had been previously shown (Populus *et al.*, 1995) that a general formula could be established for coastal waters of the Java Sea, based on simultaneous reflectance and TSM (total suspended matter) measurements.

Log TSM = 2.62 * R3/R2 + 0.90 r = 0.77 (32 samples) (2)

The final plots of computed values against measured values are shown in **figure 87** below. The residual standard deviation measures the prediction accuracy (Whitlock 1982). Its value of 0.47 (Whitlock, 1982) denotes an uncertainty of 40 % on the remote determination of TSM.

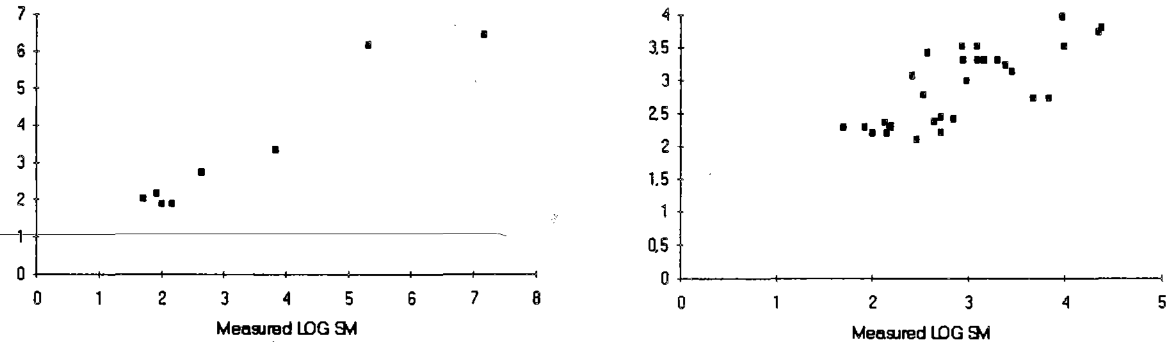
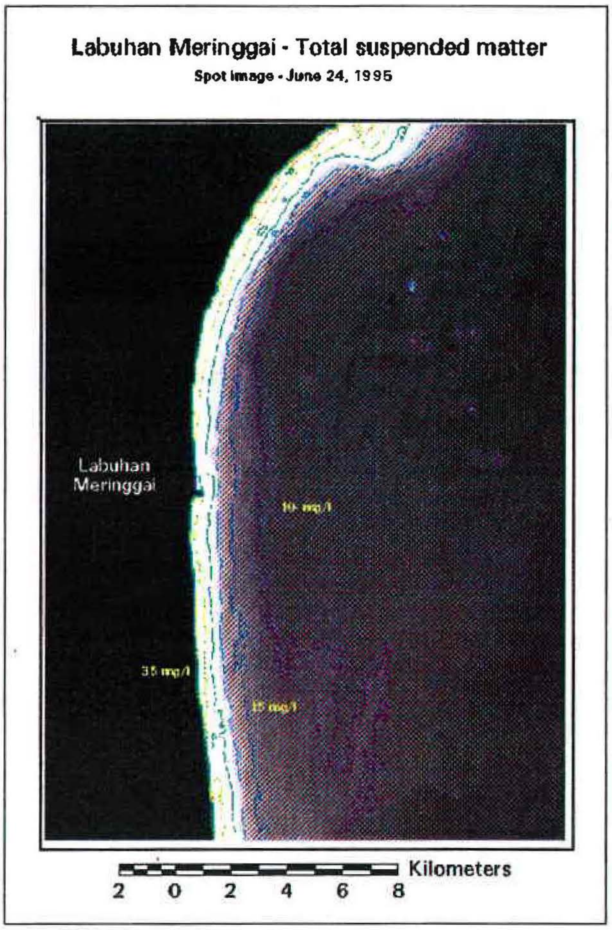


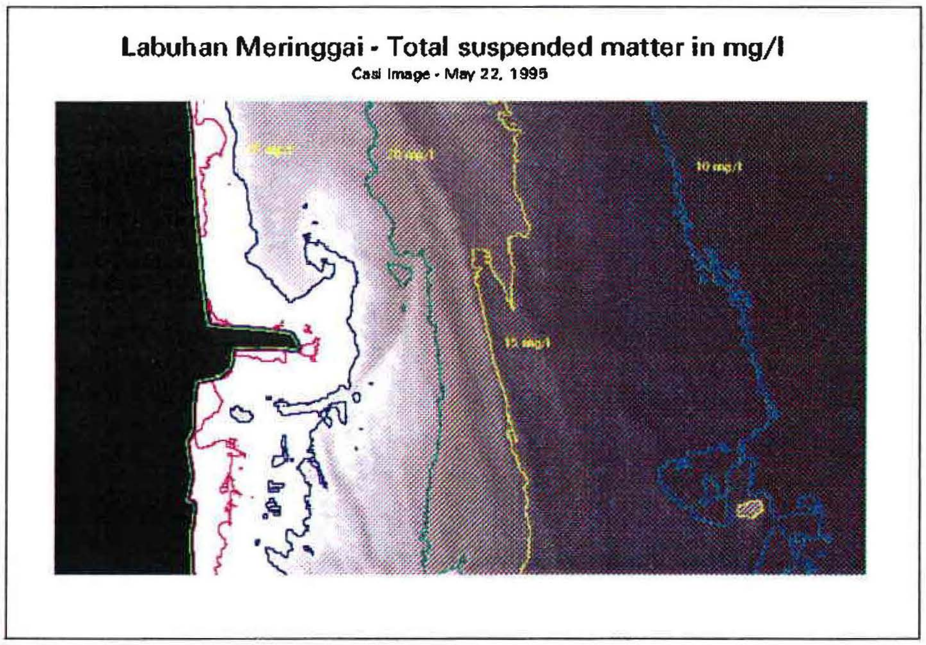
Figure 87. (a) TSM values computed from Cimel measurements against sampled values, Cirebon, February 14, 1993 ; (b) TSM values computed from multi-site and multi-date image data against sampled values (32 samples, multi-site).

Formula (2) was then applied to three types of data acquired over the Lampung coast, i.e. the October 1991 Landsat image, the May 1995 Casi image and the June 1995 Spot image, all three dates in the dry season.

Two TSM maps are shown on **figure 88**: (a) TSM isolines drawn over the Casi image of May 22, 1995 and (b) TSM isolines drawn over the Spot image dated June 24, 1995. The two data types are quite consistent, yielding a 20 mg/l line at a distance of about 1 km from the shore. This tends to prove that the two situations were quite similar, even one month apart. The one week delay that resulted from pending army clearance did not allow simultaneous water sampling. Water samples were collected on May 17, both on an offshore transect and inside a few selected ponds.



(a)



(b)

Figure 88. TSM maps derived from (a) June 25, 1995 Spot scene, (b) May 22, 1995 Casi image.

The curves of **figure 89** show TSM as measured in water samples from the Labuhan Meringgai transect, over the period 1992-1995. As a matter of fact, May 1995 values are the highest ever recorded, reaching over 100 mg/l at a short distance from the coast. The explanation for that is a possible sediment removal occasioned by unusual strong winds that may have prevailed just before May 17. It is clear that the very fine sediment grain size, due to the high proportion of clay and organic particles, makes it highly prone to resuspension. Due to such versatility, no conclusion based on simultaneity is possible and only global estimates are obtainable.

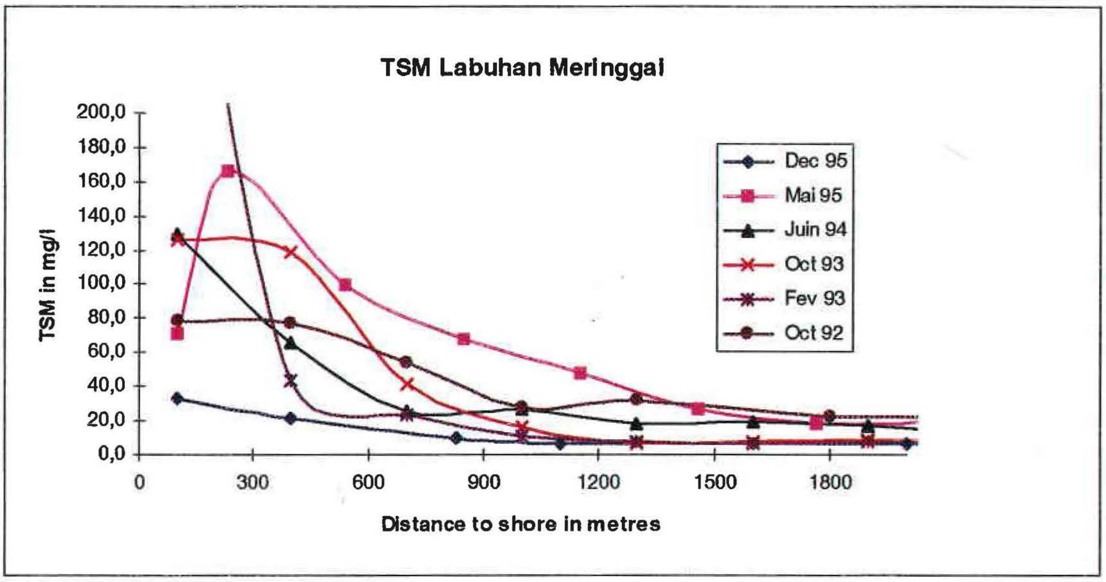


Figure 89. TSM transect over four years (92-95) in Labuhan Meronggai.

4.3.2.2. Expoiting Casi images for pond monitoring

No ground data was available to calibrate image pond data, as the region sampled in the field was masked by clouds. Besides, due to clearance postponement, pond water sampling was performed a week before the flights. A classical supervised classification was therefore not applicable, and an unsupervised classification had to be performed. In this method, a fixed number of classes (5 were selected) was defined by the user. No prior knowledge of ground truth was required by the software, which used statistical criteria based on all channels to select five representatives as different as possible from one another. It then clustered all image pixels around these five seeds according to their « spectral distance ».

This classification has only been applied to « water pixels », after all other pixels, i.e. firm ground or vegetation or anything that is not water, had been discarded by a threshold operation on the near infrared channel. The distinctive features of each class had to be assessed by looking at their spectral signatures. These signature are formed with the reflectance values in each of the 12 spectral bands of the Casi, represented as broken lines on **figure 90**. It can be seen that the behaviour of each signature is quite unique, in a reflectance range of more than 10 %, giving way to the possibility of identifying each water type with good confidence.

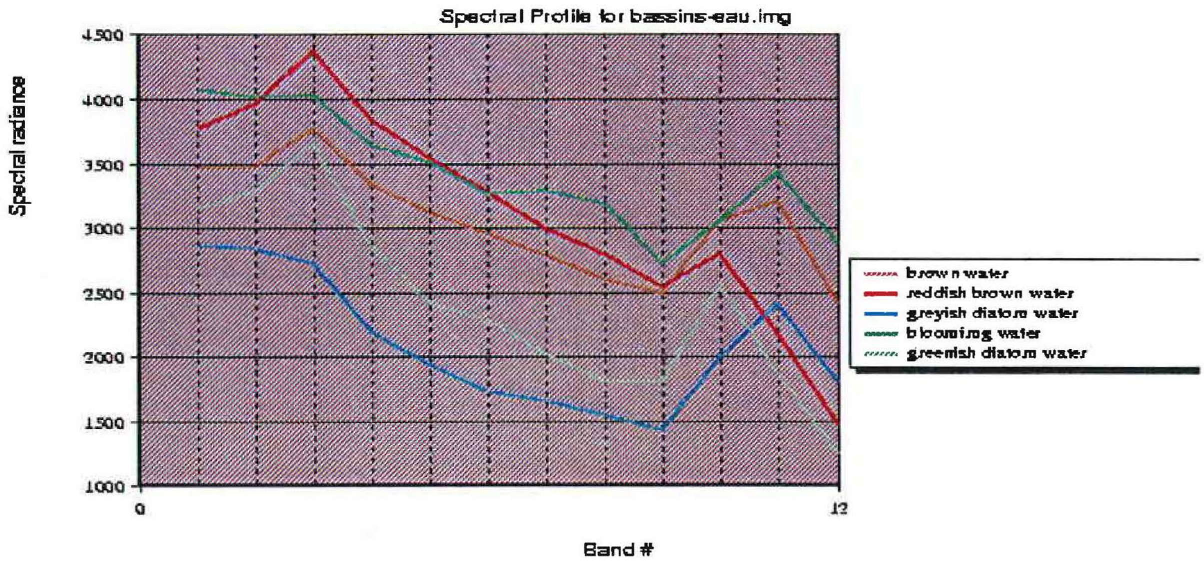


Figure 90. 12 band spectral signatures of several pond water types.

In order to try to link these curves to ground features, only the first eight bands (the visible ones) have been considered, the colour being the result of varying proportions of them. In this way, a qualitative ranking may be given to the five water types, from diatom water to blooming and cyanobacterian type waters, as appears on the caption of **figure 90**. After the classification had been performed, it was imported into Arcview under the « grid » form and overlaid to the pond contour. An Arcview tool was then readily available that performed the extraction of all the pixels overlapping a given pond and computed their number, average, and standard deviation. The pond was given the code of the class having the majority.

Figure 91 is an overlay of the Spot image, pond contours and pond class, performed under Arcview. The pond attribute table contains all features describing a pond, i.e. its area, water class type, distance to shore etc.. Distance to shore has been automatically conputed for each pond. Some patterns appear with respect to distance to the shore, especially in the southern block of ponds: brown water limited to the more inland ponds, blooming water (dark green) along the shore, diatom water (light blue, light green and red) rather in the median zone. The northern part (yet narrower) reveals no specific pattern, except maybe the light blue dominance (greyish diatom) in inland ponds.

When water supply is gravitary as is always the case in such contexts, the distance to the shore is considered an essential environmental parametre. As this distance does not exceed 1.2 km in this northern section, the effect is limited. It would gain relevance in the southern part, where aquaculture extends much farther inland (as far as 3 km).

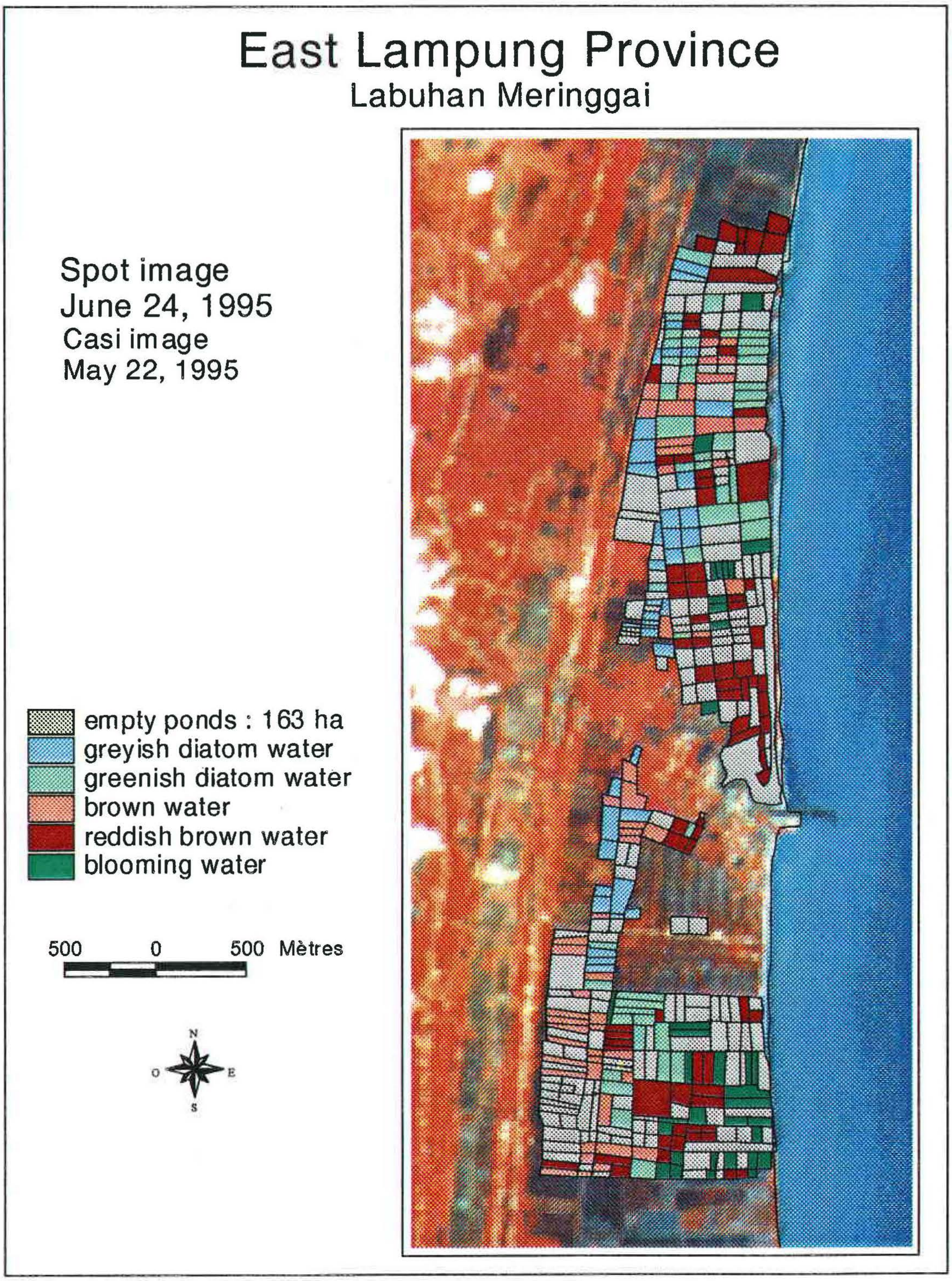


Figure 91. Pond colour classification according to spectral signatures.

4.4. Discussion

* Concerning water quality, it appears that in view of the initial objectives of the project, the impact of aquaculture on the coastal environment, quantification is very hard to achieve. Empirical relations that may be found at one time between remotely sensed and field values are not robust. No conclusion can be drawn in quantitative terms, although the relative distribution of water loads is easily shown. These relations may illustrate a certain situation but have little general value, let alone a predictive one. Coastal waters are too complex , mobile and prone to subtle changes within hours. Imagery should rather be considered as a preliminary tool to be used a) to orientate field measurement to the most critical locations, and in particular where river plumes may drastically modify the general behaviour of the coastal waters, b) to help calibrate coastal hydrodynamic models that were lacking in this project and should be recommended in future ones.

* Concerning pond water assessment, the information contained in the imagery was rich enough to characterize various types of pond water situations. Unfortunately knowledge is missing about water colour and the inference on its content, even in the more simple case on ponds which are assimilable, in terms of content, to « inland waters » (i.e. containing organic matter and cholorophyll but no suspended mineral).

4.5. Conclusion about the use of remote sensing data

4.5.1. Satellite data

At present, only two major sources of satellite data are available, Spot and Landsat, both adequate to deal with scales around 1/100000. Landsat main advantages are a) the availability of its 7 channels, of which 4 to 5 are of interest to aquaculture studies, b) its large ground coverage (40000km^2), but a drawback is its resolution limited to 30 meters. It is quite suitable to map large expanses of land such as a province for instance.

Spot is more routinely operating, with excellent delivery delays and announces a true 10 metres resolution in 1998 (Spot 4). Its other advantage is the possibility of programming the acquisition, i.e. getting a scene in a given period, provided cloud cover permits it. Its ground coverage is only 3600 km^2, which is not so much of a problem in the case of aquaculture, due to its limited areal extent. It features only three channels, but the critical ones. This work showed that a 4 metre resolution allows mapping pond cadastre, i.e. on a scale around 1/20000. It is not illusory to expect very focused images in the near future for very specific problems.

Yet a drawback commun to all satellite images is their cost. The solution to that is to have the cost supported and shared by a group of users. This call for image data acquisition and processing at a higher institutional level, i.e. either national or provincial.

The specific output of satellite image processing for aquaculture is twofold:

a) It should be used for synoptic viewing of a given coastal ecosystem, possibly in coordination with hydrodynamical modelling, either for site selection or for site monitoring. This is all the more crucial that the study area is prone to heavy discharge by rivers or various effluents, which places aquaculture in a position of threat by sediment load, low salinity waters or cyanobacterian overload. Much the same way, synoptic viewing allows establishing optimal sampling locations for field work, after qualitative assessment of total suspended matter has been performed through appropriate band ratioing of the images. Moreover, if relative amounts of TSM may be obtained, they may be used to give boundaries limits to hydrodynamical models. The present project has been missing such models to understand the fate of coastal plumes.

b) Image processing also allows mapping of the main units of land use, both natural and man-made. Were it for site selection or monitoring, the possible influence of neibourghing activities should be considered. The aquaculture perimeters themselves are easy to delineate on satellite images, if not the actual contours of small size ponds. There is quite much to see on an image that the topographic map does not show. Besides, images are renewable, which allows them to address change assessment. Of course, the degree of change should be compatible with the definition of the image. As shown above, this explains why erosion may be checked only when it has had dramatic effect on the coastline (in view of the 20 meter resolution of Spot for instance). Such phenomena as paddy to pond conversion, striking much larger expanses, does clearly appear on images.

Finally, the progress in image formats, processing hardwares and softwares make it possible for PC-bsed units to deal with images. Hence the potential decentralisation to local agencies should benefit to the necessary validation of the interpretation, a step that is too often missing for reasons of limited field data and resources.

4.5.2. Airborne data

The airborne experiment carried out in this project did not yield the expected results. Two improvements were expected, from the geometric and spectral standpoints. The geometric advantage of airborne digital data resorst to its high resolution which permits work on scales around 1/20000. In this respect the data were of excellent quality and allowed to deal with cadastral issues. The processing of such data does not imply any particular difficulties.

The spectral capabilities of the instrument lead us to expect quantitative achievements in terms of coastal water quality. Unfortunately, a lot more laboratory and field work than was affordable in this project would be necessary to get anywhere in quantitative ways. This could be the scope of a scientific project dedicated to this aspect.

For aquaculture, airborne remote sensing should be advised when a high level of detail is needed, for instance in pond contour mapping. Such an experimental digital acquisition as Casi remains rather costly, all the more when institutional difficulties make it more hazardous. When it comes to operationality, the best alternative is still probably either airborne video or aerial photography, also expensive when high geometric quality is wanted, but well mastered.

As many remote sensing labs have now the knowledge to achieve ortho-rectification, a reasonable trade-off may be found using scanned amateur air photography.

Task 5. Training course

Author : *J.Fuchs* *Ifremer /Paris*

The training programme of Asian researchers to Europe started in 1995 and has been implemented in 1996. Two kind of training are considered in the STD3 programme :

5.1. Short term training

Two training courses have been organized in 1996 for Vietnamese researchers in Europe.

Mrs Le Laan Huong from ION in Nha Trang spent two months in December 1996 and January 1997 in the laboratory of marine hydrobiology of the university of Montpellier to be initiated in the new methologies developped in Europe in the field of microbiology. Mrs Le Laan Huong works on this subject in Nha Trang and is now in charge of the analysis and exploitation of results of STD3 programme related to sulfato reducer bacteria used as biological indicator in the study of Mekong delta ecosystem. During her training, she assisted O. Guelorget in the exploitation of the results obtin in the Mekong delta.

Mr Nguyen Phi Phat and Mr Nguyen Thanh Tung. have been selected to be trained in the Centre Ocealogique of the Pacific based in Tahiti in october 1996. The two months training course focuses on the management of shrimp hatchery and grow-out technology. The objective for the trainees was to practically learn about shrimp culture management and analyse the possibility of applying these knowledges in the particular context of Vietnam where numerous problems encountered by farmers in the Mekong delta are due to poor management of the rearing ponds.

5.2. Long terme training course

5.2.1. Indonesia - BPPT

Mr Agus Wibowo, from BPPT, left Indonesia in August 1995 to ITC - Netherland for a MSc course entitled "Geoinformation System for Cadastral, Urban and Rural Application. The MSc course runs from September 1995 to February 1997. He has already successfully pass his MSc. He completed a field work related to Gis implementation in relation to the STD3 programme and spent two months in Indonesia, in June and July 1996 to collect data and precise his subject with ITC scientists and Ifremer/Sillage. He published in january 1997 his report intitled « Database design for GIS applied to shrimp aquaculture - a prototyp implementation : case study in Lampung, Indonesia. The details of the report are presented in chapter 1, Task 4.

After having completed his Msc, Mr Agus Wibowo continued to develop the system in BPPT with the assistance of ITC and Ifremer from January to August 1997.

5.2.2. Indonesia - BADC

The MSC course, primarely proposed to one BADC scientist in ITC, Holland, has been transformed after agreement into three Msc course in Indonesian universities. The first topic concerne "Environmental bioindicators" at Brawijaya University Malang, taken by Mrs Woro Hastuti Styantini. The second is "Toxic Substance on Aquatic Environment" at Gajah Mada University, Yogyakarta taken by Mr Arif Taslihan. The last course is "Water and soil Quality" taken by Mr IBM Suastika Jaya at the same university.

The three researchers selected by BADC Director have been retained for the Msc and are completing their courses.

CHAPTER 2 - A MULTIDISCIPLINARY APPROACH TO ENVIRONMENTAL IMPACT ASSESSMENT OF SHRIMP FARMING - TOWARD MANAGEMENT TOOLS -

Authors:

	J. Populus	*Ifremer/DEL/AO*
	D. Bailly	*Ensar*
	J. Fuchs	*Ifremer/Paris*
	J.L. M.Martin	*Crema-L'Houmeau*
	O.Guelorget	*University Montpellier II*
	P. Raux	*Ensar*
	A. Wibowo	*BPPT*

The objective of Chapter 2 is to discuss the possible applications of the methodologies developed during the STD3 programme in the fields of ecology, hydrobiology, economy and remote sensing to assess the environmental impact of shrimp farming. More specifically, the possible applications of these methodologies concerned two topics of major interest:

1 - Site selection: how can STD3 results facilitate and improve site selection for shrimp farming development ?

2 - Management of production sites: which methodologies and tools could be recommended to regularly assess the environmental impact of shrimp farming with a view to limiting sites overexploitation ?

In addition, investigations have been carried out to study new management tools including a GIS prototype, developed to integrate georeferenced data collected on the Lampung study site in Indonesia and to facilitate any query made on spatial variables and their attributes to reveal patterns and phenomena related to shrimp farming development.

2.1. Site selection methodologies

2.1.1. Introduction

Among the problems faced by Asian and Pacific countries to develop shrimp farming on a large scale, the question of the capacity of each site to sustain aquaculture is of major importance. Even though there is substantial literature describing all the parameters to take into account when selecting a new site for aquaculture, few methodologies have been proposed for the reliable evaluation of the biological capacity of an ecosystem to sustain aquaculture. One of the outputs of the STD3 programme has been to test a number of major parameters, resulting in the selection of a limited number of "biological indicators" presented in a single table (see paragraph 2.5, task 2, chapter 1). In addition, remote sensing technologies have been successfully tested on a larger scale to ascertain some physical and biological characteristics of ecosystems where aquaculture could tentatively be developed.

2.1.2. Ecological Approach

The success of aquaculture in terms of production and sustainability is highly dependent on the characteristics of the water entering the ponds, and thus, on the characteristics of the water in the surrounding host environment (ecosystem). These characteristics depend mainly on the structure of the ecosystem, and more specifically on factors related to:

- geomorphological characteristics (open or closed bay, straight coast line, estuary, etc.),
- hydrodynamic characteristics (seawater renewal by tide and currents),
- impact of continental pressure (input of fresh water, discharge of detritic organic matter, etc.).

These characteristics mean that some ecosystems will be better suited than others to host aquaculture. Furthermore, the same ecosystem may not possess homogenous space and time characteristics. Thus, the studies carried out in the different ecosystems showed an heterogeneity, which is weak in coralline sites, and much higher in mangrove and delta sites. As a consequence, the same ecosystem may show a gradation in its capacity to host aquaculture, depending on the location within the ecosystem. This location will influence the water quality, and the ability to assimilate or to evacuate waste. *This is why the first step in site selection is to determine the structure and the functions of the selected potential ecosystem. This enables us to (i) determine the capacity of the ecosystem to host aquaculture, and (ii) to determine the best place for the activity inside the ecosystem.*

Which indicators ?

The choice of parameters, for site selection and activity locations, must take into account those which show the characteristics of the ecosystems and of the effect of these characteristics on water quality. Two categories of parameters have to be considered:

- Hydrobiological parameters: T°, pH. A special emphasiss must be laid on salinity. This parameter enables to determine the impact of continental freshwater input, stratification, seasonal variations in the distribution of mass water, etc.
- Parameters related to organic matter discharge: The continental pressure is strong in mangrove and delta environments. It takes the form of a discharge of detritic organic matter into the coastal ecosystem. This discharge will have an impact into the environment, in terms of:
  - Concentration of total suspended matter,
  - Concentration of particulate organic matter,
  - Concentration of chlorophyll and pheophytin (trophic level) and relative ratio,
  - Oxygen concentration,
  - Bacterial indicators,
  - Sulphate-reducing bacteria,
  - Cyanobacteria.

The effects of continental pressure (organic matter discharge), in synergy with the confinement of the ecosystem (seawater renewal rate) and the oxygen deficit, may lead to a state of dystrophy, with the consequent development of the bacterial populations that are specific to this kind of environment. The results of our study showed decreasing concentrations of sulphate-reducing bacteria in the water and in the sediment, and of cyanobacteria in the water, from the most continental area to the most oceanic one. These two kinds of bacteria can be considered good indicators of environmental quality.

Nevertheless, it should be noted that even though the analysis of sulphate-reducing bacteria does not raise any special difficulties, the determination of cyanobacteria populations calls for very sophisticated and expensive techniques (flow cytometry).

Remark: *It should be noted that the parameters above are also influenced by the discharge of organic matter (including waste from aquaculture), and that they can be considered for a survey of the impact of aquaculture waste on the surrounding coastal environment (see the relevant section below).*

Which strategy ?

It would be unrealistic to define a single strategy for studying the structure and functions of ecosystems. The strategy must be adapted to the type of the ecosystem under study. It will be elaborated after a preliminary analysis to determine the need to carry out horizontal and vertical transects to position the sampling station. The strategy will be different depending on whether the ecosystem is a coralline, a mangrove area, a bay, or a delta, depending on the water depth and the amplitude of tides. Knowledge on this particular point can only be tranferred through the experience obtained during field study.

Determining the general characteristics of the ecosystem and the water quality at different places within the ecosystem, using the parameters selected (see above), enables to refer to the scale elaborated. This help in determining the production potential of the site (expressed as T/ha/year). Furthermore, if the sampling strategy is well thought out, the data may facilitate the determination of which area within the ecosystem is the best suited for implementing the activities. Finally, the knowledge of the structure of the ecosystem is necessary to determine the best strategy for managing water renewal and waste discharge: location of the pumping station or of the mouth of inlet channel, location of outlet effluent, etc.

As the example of Jambi will illustrate it below in 3.1.4 , the inability of policy-makers and resources managers to fully understand the underlying causes of environment stress has contributed to inefficiencies in addressing management issues of the fragile coastal environment. Sectoral approach still prevails in the management of coastal resources. This might be due to a number of reasons including: the lack of implementable management strategies to resolve immediate environmental problems, an insufficient data base for multi-sectoral plan formulation and strong pressure both from the economical and the political sectors towards the development of rural areas. The case of Sumatra resorts to this analysis, where in the framework of the transmigration policy, proper sites have to be defined for development of rural activities, in particular paddy and coconut plantations and coastal aquaculture.

2.1.3. Use of remote sensing for site selection

In the field of coastal aquaculture and particularly shrimp rearing, site selection has been addressed by many authors in a number of locations around the world. Works and reviews were written by FAO (Kapetsky), who addressed the use of both remote sensing and GIS. Some methodological and operational work has also been conducted in New Caledonia by Loubersac (1991) and in the Philippines (Populus, 1991), relying heavily on the use of Spot imagery.

In general, these works have concentrated on the inland aspects of the sites. Remote sensing has been used to give at the same time a synoptic view of the environment, i.e. general natural and human facts characterising a given coastal stretch, and a detailed inventory of several suitability factors.

- The topography could be approached by interpreting the imagery.
- The physiography (usually referred to as « land use ») could be mapped, depicting the sites with a view to developing aquaculture (tidal areas, mangrove and the like...) as well as the surroundings (conflicts with other activities, rivers, pollution sources etc....).
- Some human activities or logistics could be appraised.
- It has sometimes included the mapping of shallow sea bottom, when water transparency allowed it, either for purposes of shallow water aquaculture, or for assessment of access by sea.

In most cases, the study of the initial quality of the water has been neglected, either by lack of data, or as a result of the assumption that the quality was suitable and not a matter of prime interest. Even when the quality lodes good, (see in this project the example of the site of Merak Belantung, referred to as « Coco Bay »), it is clear that in order to plan development and edict sensible limits, more knowledge rapidly becomes necessary in this regard. Section 4.4 (task 4, Chapter 2) above gives a recapitulation of what may be expected in terms of dealing with coastal waters. Remote sensing may only complement hydrobiology and hydrodynamics, which remain the basic sciences for environmental assessment.

2.1.4. Case study in the Jambi province, Sumatra

The methodologies developed during the STD3 in term of (i) characterisation and functioning of ecosystems (ecological approach), (ii) land use occupation and water quality (remote sensing) have been applied to a case study to evaluate the relevance of this approach. The study has concerned the Jambi province (see **figure 92**) which was a site intended for transmigration and thereby under assessment for a large shrimp aquaculture development project (5 to 10 000 ha). The field work has been carried out in June 1994 and the data have been analysed and the results exploited following the methodologies developed during the programme.

The region is a deltaïc system part of the distributary area of the eastern Sumatra river catchment. The bay of Kuala Tungkal looks like a circle arc about 100 km wide and 70 km deep where the pressure of fresh continental water is very strong. The concavity of the coast and the presence of the Kepulauan Linga islands lying offshore tend to squeeze these waters. Little mixing is therefore expected to occur between the offshore Java Sea waters and the considerable amounts of discharge from this coastal deltaïc system. The consequences are on one hand the remanence of desalinated water in the bay and on the other a high rate of sedimentation of detrital material influencing the evolution of the shoreline.

The Jambi bay is bordered by mangrove that ascends upstream along the tributaries and affluents. It is composed of four types typical to the Indonesian coasts: *Bruguiera*, *Rhizophora* and *Avicennia* and *Sonneratia* They testify the presence of little marine water at the edge of the bay but as soon as penetrating the estuary itself these trees are quickly replaced by dominant *Nypa*, indicating the influence of permanent freshwater inputs. Upstream *Nypa* disappear in the transition zone towards the continental domain. All this ecosystem is virgin with little anthropic pressures. The bay is in an entirely natural state.

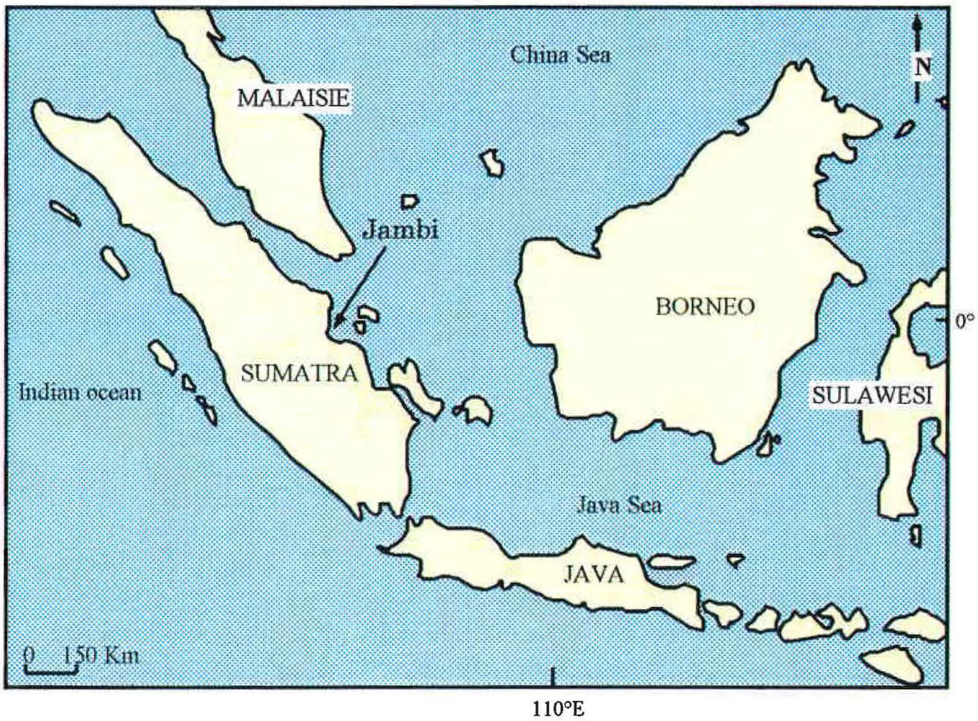


Figure 92. Location of Jambi, in Indonesia.

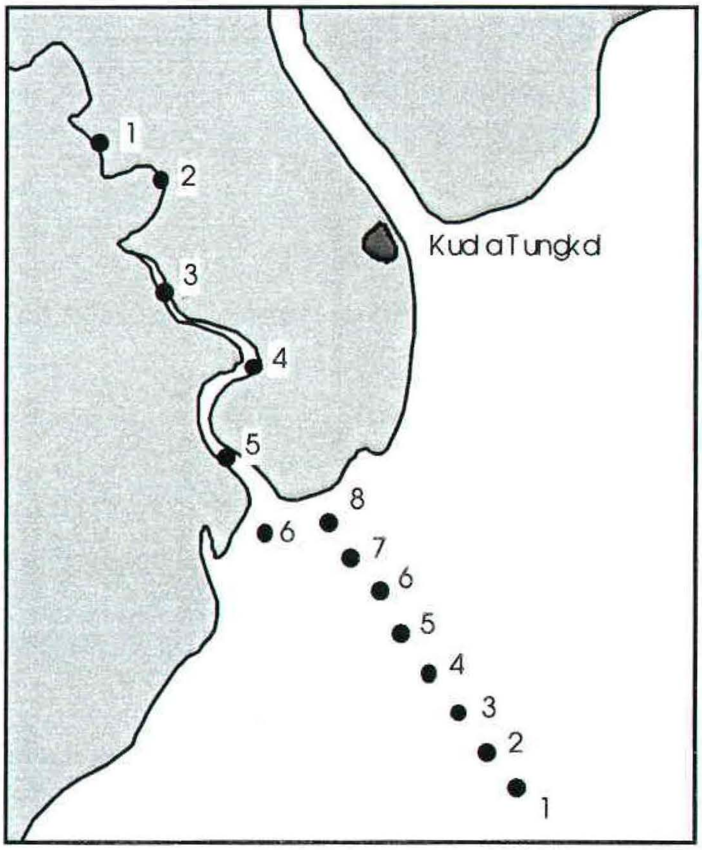


Figure 93. Sampling locations.

The coastal plume extends its heavily laden waters on a distance of about 10 km offshore. The 4 meter depth line is reached at only 500 meters from the coastline. Field sampling performed in June 1994 (dry season) indicated a general salinity level of less than 20 ppm in the site vicinity, a value which would be even lower during the rainy season.

Along 14 stations situated firstly in the Jambi bay and secondly in the Betara estuary (see **figure 93**), suspended mater ranged from 61 to 1530 $mg.l^{-1}$. Means are respectively 267 $mg.l^{-1}$ in the estuary and 525 $mg.l^{-1}$ in the bay with a maximum located at the transition zone between the two systems. The contribution of organic matter to total suspended matter is from 9 to 25 %, with a difference between the station 1 far from the contributions and the whole system. The mean percentage is 13 % in bay and estuary. Chlorophyllian biomasses are variable from 1 to 43 $mg.m^{-3}$ and phaeophytin from 4 to 31 $mg.m^{-3}$. Phaeophytin is always more than 50 % of chlorophyll, with a maximum of 100 %.

The values recorded in Jambi waters have been included in the scale of productivity according to hydrobiological parameters. The specific hydrobiological features of the Jambi bay ecosystem are reported on **table** 75 below.

Table 75. Hydrobiological features of the Jambi ecosystem.

Site	MES $mg.l^{-1}$	MO %	MO mg.l	Chla $mg.m^{-3}$	Phéoa $mg.m^{-3}$	Phéo %
Study zone	120-1530	15-25	20-390	4-43	16-31	65-100

It should be stressed that there is a high variability between the open bay, the edges and the estuary. An aquaculture project aiming to settle shrimp ponds with a pumping station near the mouth of the Betara estuary would concern a more restricted zone.

Following the scale, in this particular zone waters could theoretically accept a production up to 0,6 tons/ha/year. But it would be a first estimation. It is a natural ecosystem and continental pressure is limited to freshwater inputs. Aquaculture farming would change all the data by increasing organic matter and possibly chlorophyll biomasses. This system is well balanced, and in this situation could not maintain a strong production which would decrease by self-enrichment of the waters.

Coastal mangrove mapping performed with the satellite image shows the presence of two species characteristic of desalinated regimes, i.e. *Nypa Nypa* and *Sonneratia Caseolaris*. The former is currently found on stabilized brackish grounds, occupying all the lower levels of coconut planted soils. The latter is a typical pioneering mangrove that forms a 300 metre wide « buffer » along the shoreline. Younger trees a few feet high grow on newly deposited sediments and tend to fix them, while older ones at the back may reach a hundred feet. As a result of the size and growing rate of these trees, it may be assessed a horizontal expansion of the siltation processes of a few decameters per year, more pronounced at distributaries mouths, and specifically at the project site. A comparison has been made between the 1992 image and a 1978 Landsat MSS situation in order to estimate the gross coastline change in fifteen years. The result for a farm would be that after some time it would lie more an more inland, thereby increasing technical problems of seawater pumping. Moreover, the water sampling nearshore as well as in the estuaries showed no water stratification which means that even pumping deeper would be of no effect.

These results clearly demonstrate that the Jambi site does not appear quite suitable for shrimp farming. Decision-makers finally decided to stop the investigation on this area considering that, based on experts opinions, the long-term sustainability of the project had not been demonstrated.

2.2. Management of production sites

2.2.1. Introduction

One of the major problems encountered by decision makers in charge of the planning of aquaculture development is the difficulty in predicting and controlling the development in order to avoid sites overexploitation. The major constraint is the difficulty to obtain accurate and regular information coming from different sources and the absence of management tools. Few investigations have been carried out on the possibility to (i) accurately follow the development of the activity to prevent any overexploitation (iii) limit potential conflicts with others users.

The results of the research conducted during the STD3 project on the interactions between shrimp aquaculture and the environment are discussed in terms of possible applications for the regular assessment of the impact of shrimp farming on the environment in view of limiting these problems. The discussion concerns (1) the data which have to be collected both at the level of farms and at the level of the whole ecosystem to follow the evolution of the system, (2) the possible methods and tools to develop in order to facilitate diagnosis.

2.2.2. Data collection

2.2.2.1. <u>Data collection guidelines at farm level</u>

2.2.2.1.1. Baseline geographic data

Baseline data consists mostly in general locational information, usually obtained at medium scales on the order of 1/50000 and smaller, as is described below in 3.2.2.2. The scale needed when considering farms and ponds is rather above 1/20000. If the position and other geographic facts about given farms or ponds are to be mapped (i.e. surface area, perimeter...), then the pond cadastre has to be elaborated through mapping techniques based on air photography. At such scales, baseline data also includes the coastline, as well as roads, paths and the network of water canals.

The Program has shown that digital airborne data such as Casi's were ideal to rapidly deliver cadastral contours, due to their high scale and good geometric quality. However this technique is an expensive one, still rather experimental, which cannot yet be contemplated on an operational basis. Classical air photography would allow the same kind of restitution, provided the photos are geo-referenced.

2.2.2.1.2. Economic data

The collection of economic data on a regular basis to support policy-making and policy evaluation is discussed here only in the perspective of the comparative analysis of production systems (cost-benefit, risk analysis, organisation) or of the comparative analysis of sites (ecosystemic determinant of economic performance). The type and volume of information to be collected is a trade-off between the quality for interpretation (representativeness) and the cost of data collection and management, including the statistical processing, the interpretation of results and the transfer to potential users. The strategy for data collection is discussed here, keeping in mind these objectives. The first concern is the identification of the type of observation units and the rhythm for data collection. The second is the structure of data aggregation relevant for economic analysis. This is necessary to design the farm sample so that the various levels of variability of interest for analysis or policy-making are well represented. Three dimensions are considered for aggregation: geographical, technical and organisational. This provides the ground for a sampling strategy. Finally the variables needed and the rhythm of data collection to make the database useful for economic analysis are briefly discussed referring to the experience of the survey conducted during the project and presented in chapter 1, task 3 in the case of Lampung province, South Sumatra, Indonesia.

*** Identification of observation units**

The basic unit of observation for a quantitative economic analysis of shrimp production is the farm which is the private decision-making level. Therefore economic data concerning costs and benefits or technical characteristics and performance, will have to be collected at the farm level. In terms of technical production system, the farm is probably best represented by the performance of one pond representative of the dominant production strategy in the farm. For other aspects like size of operation, marketing and financial strategy, diversity of production strategies within the farm or risk evaluation, data will be collected for the whole farm. Other economic information concerns items like taxation, shifts in demand or macro-economic determinants of input and output price formation. From the survey conducted in Lampung province we may say that those are determined outside of the Province in the case of shrimp, at the national or international levels. Therefore no other level of observation than the farms appears necessary to grasp the economic internal variability of the shrimp production at the Province level. This is within the limits of the intended use of this database.

*** Sampling strategy**

Sampling refers to the selection of a limited number of observation units that would ensure both representativeness of each component of variability and consistence for time series analysis while keeping the cost of database maintenance not too high. The quota technique is used to develop the sampling strategy. This technique consist in designing a sample as a small-scale model of the studied population. The purpose is to choose few characteristics which are well known to illustrate the diversity of cases within the whole population. Then, the structure of the sample is built on the identification of cross-character groups and a number of units to be surveyed in each group considering probability distribution. Then within each group, the selection of the appropriate number of units to be surveyed is made on a random basis. The quality of the information, its representativeness and the possibility of aggregate the results to estimated global figures depends mainly on the fact that biases are as far as possible avoided in this random selection process. For example, selecting only the known best farmers for a farm sample survey introduces a strong bias that makes the results very difficult to interpret. The main advantages of the quota technique are a lower cost and a shorter delay than those of a global random survey. Results are also more reliable and the scope of interpretation is broaden. On the other hand, it's impossible to calculate error margins, those of a global random survey are taken into account as an approximation. The main levels of variability discussed here to form reference groups are geographical, technical and organisational. The first is given more place as it is the main scope of the STD project, but the two others are the basic for the economic analysis.

The size of the sample should be sufficient and its distribution built so that aggregating them at different geographical scale makes sense. The results of the study show a strong coherence between the economic analysis and the ecosystemic approach. The problem of defining coastal ecosystem units has been discussed in other places. This coherence seems to break up in the case of Lampung Province when the analysis is brought at the village level. Difficulties encountered by shrimp farming and common management needs rarely happen within one village administrative limits. Either few villages are concerned together or only a group of farmers within a village. Furthermore very little internal variability has been found at this stage at the village level due to mimicry phenomenon. Therefore villages appear more as social levels of collective action implementation than a significant level to analysis variability within or among villages. To allow a village comparative analysis would inflate the need for farm data without necessarily providing useful information. Information about villages is more needed in qualitative terms of policy implementation and collective action evaluation which is crucial to management but out of the scope of a follow-up database structure. If we search for some link between ecosystemic units and administrative units, the district (kecamatan) level may appear the most effective in the case of Lampung province. This fact is also mentioned when looking at the possibility to develop a GIS. But the need to ensure statistical representativeness of the sample at this level is not evident for the same reason as for the village level. It is in fact a matter of relative consistence between any administrative border and ecosystemic frontiers that should be looked case by case. The interest to aggregate at the kecamatan level refers more to the fact that it is a level administratively recognised and managed as such while the village is governed only by customary law and practices. But searching for representativeness at the kecamatan level may in some cases be very inflatory. Aggregation at the regency level (kabupaten) generally doesn't involve supplementary data collection work to ensure representativeness but it may not be relevant to the analysis of the link between natural environment and economic performance. Thus, in geographical terms, aggregation of farm data seems relevant for the intended economic analysis at the following levels. First and by far the most important is coastal ecosystemic management units. They have been identified in the course of the project but would probably need to be more precisely discussed. They will also have to be defined and probably to be given some consistence for administrative and policy implementation purposes. That refers to the creation of institutions like agencies or other management frames. Second the various administrative levels, which is the first concern for the production of exhaustive statistical information (production, area, number of farms...). The district, the regency and the province seem sufficient while it may not be necessary to ensure representativeness at the district level.

For the technical criteria to discriminate among the production system, the proposition is based on the multivariate analysis results of the detail survey presented in the previous chapter. The stocking density appears as the real indicator of technical choice. Thus, the clearly defined typology during the farm management analysis, remains the base of the different technical groups which will be sampled. Namely, the traditional (until 3 PL/m^2), the traditional + (4 to 6 PL/m^2), the semi-intensive (7 to 15 PL/m^2) and the intensive (more than 15 PL/m^2). There are no statistics about the farm geographical distribution per technique. Nevertheless, this distribution exists per area although the official statistics don't distinguish the traditional + which is recorded with the semi-intensive. Another technical criteria might of interest to discriminate among the various techniques applied for intensive production. Earth pond, plastic liner and recirculation are the main system applied today for intensive production. In Lampung, this represents today the difference between the production systems in the southern part of the province on one hand and Dipasena (liner) or Bratasena (recirculation) on the other hand. But some attempts to develop recirculation systems in the area of Penengaham is a sign that this distinction may be of interest for the future. Concrete pond system is also well developed in Kalianda area. The future may show that some of these systems are not viable. But the database should provide the frame to follow all these initiatives.

Organisational criteria are fundamental to analyse the economic dynamic of an industry. Beside the choice of production technique mentioned above, that refers to choices in the fields of marketing, financing, human resources management, ownership structure. The major difference in terms of farm management in Lampung province have been well described by the STD project. The consistence with geographical areas is well established. So it doesn't appear necessary to add many criteria of management strategy beyond the technical one defined above. As an indicator to differentiate among pure family base units from these employing a significant part of wage labours, the pond area only (a size indicator) is proposed to form the structure of the sample. Such a size indicator is often correlated to many over characteristics of farms management, it is also a good indicator of concentration phenomena and it is an information generally recorded by the administration for land ownership reasons. Therefore it may be both of interest for the economic analysis and for the statistical analysis.

** Sample structure and survey timing*

Based on the above discussion, the characteristics suggested to build the sample are the variables "coastal ecosystemic type", "kecamatan", "stocking density", "pond area" and "pond type "(for intensive only). Statistical representativeness is ensured at all these levels in the sample structure proposed here. This is based on the rule that each class should be exhaustive of the actual population or count a minimum of 30 units for the inter-group variability analysis. When crossing two variables, this representativeness is still ensured in most cases as long as the "kecamatan" variable is not used. At a higher level of cross-analysis, statistical representativeness is generally not obtained. Reference to the total population gives a rough estimate of the sampling rate. But for most variables the reference population cannot be quantified in the present state of administrative statistics. The possibility to improve the evaluation of sampling rate is discussed later under the heading *"census and survey"*.

The survey should be conducted on three geographical groups of farms: southern part of the Java sea coast (Pantai Timur), Indian Ocean coralline bays, northern part of the Java sea coast (plasma farm system). Beyond the geographical distribution of farms, this covers well the "ecosystem type" distribution, the technique differentiation measured in terms of "stocking density" and also the management type (plasma, family business, small enterprise). The existing human and financial resources at Dinas Perikanan should allow for an annual survey of about 300 farms. This is provided that data management tools (computer hardware and software) and capacity to operate them are significantly upgraded by investment in material and training of staff. The best timing of the survey seem to be an annual basis. But the survey should provide information of the specific outcome of each of the two cycles. The best period to collect data would probably be after the dry season crop, i.e. August/September.

Pantai Timur

The low intensification level farms (T and T+) are placed along this part of the east coast and represent more than 75 % of the farms. Comparing detail survey (99 farms) and general survey (1.000 farms) data gives the following distribution inside this group: 55 % of traditional and 45 % of traditional +. Thus their relative importance is not considered significantly different. 40 farms of each type shall form the sample to be selected randomly in each kecamatan according to their relative importance. The semi-intensive farms account for the rest of Pantai Timur farms, that is to say less than 25 %: 45 farms of this type are included in the sample. They are mainly located in the northern part of the area. As the area seems to be already at or beyond a full occupation for shrimp farming, it is more likely that this sample structure will remain quite stable for a while.

Indian Ocean coralline sites

Among the 70 farms on the south coast, there are few traditional and traditional + techniques. And these aren't located in coralline bays but rather at the bottom of clayish bays in mangrove areas, which tends to confirm the hypothesis that the choice of the level of intensification is heavily constrained by the coastal environment. Although they are marginal, it would be interesting to investigate few of these farms to obtain a standard for comparison with the east coast situation. The number of 5 is arbitrary set as the future of these farms was very uncertain at the time of the survey. This category may have to be dropped in the future. For the concerned ecosystem (coralline site), the intensive system is prominent compared to the semi-intensive technique (75 to 85 %). 32 intensive farms will be then selected. Semi-intensive farms are mainly useful for a calibration (comparison) with the east coast. 10 semi-intensive farms will be chosen for a minimum significance. It is on this coast that the potential for development is the highest but also the possibility of conflict leading to the stop of shrimp farming is some place. Therefore the sampling structure should be readjusted according to the evolution of shrimp farming.

Plasma farms

For the Plasma farms, the carrying out of a detail survey doesn't seem to have an official authorisation from the Companies. Under the condition that the possibility is offered, the survey should be conducted on a limited number of farm and probably with a shorter questionnaire, many aspects like investment costs, operational costs or farm management being very similar. The main questions are to compare the performance of different type of technical system, to evaluate the impact of a centralised management of water circulation and to see the variability of performance among the farmers using the same technique. Fifty farms for Dipasena site, at the rate of 9 farms per block of which 6 with a family structure and 3 with an "unmarried" structure (the farmer family doesn't live on the site but stays in its village). Due to the important homogeneity of Plasma groups, 6 blocks (on 17), placed at regular intervals from the north extremity of the site to its south extremity, seems enough to follow the farms evolution. A similar approach should be applied to the Baratesena and any other plant to be developed in the future on the plasma principal. Considering the social importance of these two sites and the potential impact of wastes to southern site, the public interest to follow their performances are not questionable. This information might also be of interest to their private developers.

To be able to analyse difference in terms of farms size, a structure of the sample is proposed in terms of pond area criteria. The limit is set at 2 ha for traditional, traditional plus and semi-intensive systems; at 4 ha for intensive production. It is important that from one year to the next the size of sample be kept similar but the individual might not be all the same. It would still be preferable if a sliding sample strategy is applied that the core of the sample (majority) of the farms, be stable. The proposed sample structure is summarised in **table 76.**

Table 76. Sample structure for an annual shrimp farm survey.

Kecamatan	T	T+	S-I	Intensive				Sample size	Reference population
				earth pond	concrete	liner	recirculated		
Labuhan Maringgai	30	30	30	-					
Jabung	30	30	6	-					
Palas	10	10	3	-					
Penengahan	10	10	6	-					
Pantai Timur	**80**	**80**	**45**	-				**205**	**2 676** (1995)
Kalianda	-	5-	-	5	5				
Kota Agung	-	-	-	6					
Wonosobo	-	-	-	6					
Padang Cermin	-	-	10	10					-
Coralline site	-	**-5**	**10**	**27**	**5**			**47**	**70** (1995)
Sub-total	**80**	**85**	55	**27**	**5**			**252**	**2 746** (1995)
By pond area									
< 2 ha (4ha for Int.)	40	45	47	10		–			
>=2ha (4ha for Int.)	40	40	8	17	5				
Plasma farms									
Dipasena						50		50	**9 000** (1997)
Baratasena							50	50	**5 000** (1997)

**** Items to be surveyed***

The economic database is only one component of a broader data system. Therefore most of the bio-technical characteristics considered here are redundant with other components of this chapter. They are repeated here to insist on their specific interest for the economic analysis. This selection is a minimum selected from the experience conducted for the STD project. A regular survey cannot be as detailed as a one-off survey that use a 10 pages questionnaire in the case of the STD project. That should be intermediate between the general survey questionnaire and the detailed farm survey. A two to three pages questionnaire should be enough to cover the items presented here. These are only list under various headings. The practical format to collect the data is left to the persons who will be in charge of its implementation. Data to be produced by the database are of two kinds: data collected by questionnaire in the field and data to be produced by rearrangement of the basic information (sums, means, ratios,....). The relation between source data and output data for an economic analysis has been detailed in chapter 1, task3. The main structure of the information needed is summarised without going back to the differentiation between the data to be obtained from the farm and the data to be produced by calculation. The way to collect these data is best illustrated by the questionnaire used for the STD survey and included in task 3 "material and methods" presentation. In terms of costs, only items representing on an average basis more than five % the total costs are surveyed. The general category of general expenses can be added on the basis of a fixed percentage of the recorded costs. The reference figure might be set at 10 %. Further research might be useful to estimate more precisely this figure.

The first group of data covers general information about farm structure and management including:

- resources ownership and management authority structure,
- pond area and number of ponds,
- structure and cost of labour,
- structure and cost of investment (common to all ponds),
- check list on problems,

- size of shrimp at crop,
- total production,
- number of ponds where production has failed, partially failed or be successful using a qualitative indicator (for each cycle) to be used to calculate a failure index at the ecosystem level,
- share of market outlets,
- financing of investment and operational costs (self financing, credit).

The second are parameters of pond management based on the most representative pond of the farm activity including:

- main parameters of pond design (area, depth), location (distance from shore), connection to external resources (nature of water supply and disposal, waste treatment),
- stocking density as the key parameter of the level of intensification,
- an indicator of oxygenation such as the investment in aerators per ha with the hypothesis that efficiency is proportional to cost or any technical variable expressing the power of aerators; this is discussed below as it has not been possible in the STD economic survey,
- an indicator of water renewal; this is also discussed below as it has not been possible to implement in the STD economic survey,
- pond production at each cycle and indicators of efficiency (survival rate),
- investment costs specific to the pond: mainly aerators, power generation system and water management system (sluice) if individualised by pond,
- operational costs specific to the pond (PL, feed, labour and energy).

The third are economic and financial performances of the operation and distributional impact of the activity, mainly to be calculated using basic data and macroeconomic data like interest rate:

- benefit/cost, benefit/income ratio,
- returns on investment (Internal Rate of Return, return period),
- labour intensity ratio (labour on capital),
- added value structure (intermediate consumption, depreciation, labour expenditures, profit) and ratios,
- ratios of inputs (quantities and costs) by kilogram of shrimp produced, by hectare of pond and by unit of equivalent full time labour.

**** Census and survey***

A sample survey generally provides sufficient information on main trends and characteristics of the major group forming the structure of the sample. But it cannot be used to estimate figures for the whole industry unless the quantitative structure of the whole population is well known in terms of the sampling groups. Such reference information may be available from data collected for the ordinary administrative and statistical purpose (ownership records, production, number of farm, area of pond). These data are generally aggregated according to administrative level and can eventually be reorganised according to ecosystem units. Although their quality is often questionable and they are resource consuming for a very limited contribution to public policy, these data have to be collected by administrative obligation. The possibility to improve the quality and the efficiency in gathering and processing these data must be first carefully thought about. The present condition of shrimp statistic production in Lampung province are archaic due to the lack of resource by the concerned administration. This could and should be rapidly improve by a minimum investment in computers and staff training (for computer use and for statistical methodology). A sample based database would be impossible to implement if this is not done.

Another complementary approach would enhance the contribution of databases to the management of shrimp farming. This is by considering the possibility of producing exhaustive information on a regular basis of a census type. This consist of using the resources and material of ordinary administrative statistical work to realise a general survey which provides more information than ordinary requested without being as detailed as the sample survey. The time of such a census might be every five years. More than for the sample survey, the management of a census requests that the organisation of data management by the administration is rapidly upgraded.

In any case, sample survey only or census and survey, it should also be kept on mind that such a database will be useful only if some parallel efforts are devoted to collecting more detailed qualitative information in relation with the policy-making agenda. It is important also that a management decision-making frame be set to provide incentives to the actors of the management (administration, producer, political leaders, planners,...) to contribute to its implementation and the active use of its outcome. The implementation of such a database can only provide a significant contribution to policy-making and policy-evaluation if it is:

- seriously managed in terms of consistence with statistical rules of sampling and of consistence over time,
- designed as a tool for well identified users that should be involved in its implementation and receive already processed and pre-analysed results,
- supported by the major levels of administration concerned, political will and by producer group representatives.

In the case of Mekong delta, the same methodology could be applied. Nevertheless, the lack of official accurate statistical data conduct to simplify the sampling strategy as presented in **table 77 and 78**:

Table 77. Main profiles from multivariate analysis.

		Extensive farms	Ext + very low density and bad efficiency	Ext + low density	Ext + high density	Long Toan
Area (ha)		9,9	10,9	2,2	2,4	0,2
Stocking density (PL/ha)	Average	-	12 738	19 271	38 252	42 553
	Min	-	2 500	3 000	15 000	24 000
	Max	-	20 000	40 000	77 143	60 000
	SD	-	3 654	10 834	17 796	10 022
Production (kg/ha)	Annual production	93,3	63,4	99,4	187,5	1073
	Dry season	-	23,3	96,3	140,2	1016
	Rainy season	-	-	23,1	90,4	-
	Natural shrimp	93,3	55	-	36	170
Family workers	(nb/farm)	3,1	4,9	4	2,1	3,4

Table 78. Sampling strategy.

Area	Extensive farms	Area	Extensive plus Low stocking density farms
No Size	**30**	< 2 ha	**15**
		> 2ha	**15**
Area	**Extensive plus High stocking density farms**	**Area**	**Extensive plus High stocking density farms Small pond**
< 2 ha	**10**	< 0,25 ha	**20**
> 2ha	**10**		

2.2.2.1.3. Environmental data

In addition to the improvement of pond management (water supply, seed, feed, waste discharge...), the follow up of the quality of the water entering a farm or a group of farm is of major importance to evaluate the <u>evolution</u> of a site under aquaculture pressure. Only a regular check of the characteristics of the water entering the farms should permit to really identify and follow an eventual degradation of his quality on a long term basis. Nevertheless the administrations in charge of the follow-up of the development are generally reluctant or event not equipped to develop such network due to his complexity and the cost of maintenance. Based on the field observations accumulated during the programme, we propose to discuss the possible strategy to apply and the main parameters to take into consideration for such an objective.

Major parameters to be followed in the water

As previously mentioned, the impact of wastes from aquaculture deal with organic sewage discharge and impact. So it is through the survey of the parameters related to organic matter that the survey must be carried out. The impact of organic matter on water quality can be evaluated through direct measurements, or through the consequences of its degradation and/or mineralisation under aeroby or anaeroby conditions. So, from the easiest to the most sophisticated, the analyses which may be carried out are the following ones:

- Oxygen (analyse with probe),
- Total suspended matter: gives information on the impact of continental pressure and of aquaculture wastes,
- Particulate organic matter: same as precedent + plus nature of the particles,
- Chlorophyll and phacopigments (including relative ratio): indicate the level of dystrophy of the water, and the « health » of the phytoplanctonic populations,
- Organic carbon and particulate nitrogen (including ratio): gives information on the nature of the organic matter,
- Sulphate reducing bacteria: integrate the relationship between input of organic matter and deficit in oxygen (excess of organic matter and/or low rate of water renewal of the ecosystem),
- Planktonic assemblage (including cyanobacteria): gives information on the dystrophy of the water.

The level of information given by such analyses varies with the parameter analysed (as well as the cost!), and all these parameters cannot be analysed everywhere. So, a solution must be found, and we can consider that the analyse of oxygen, total suspended matter, particulate organic matter, and, if possible chlorophyll-a and pheophytin may constitute a compromise (between the sophistication and the cost of the analyses on the one hand and the sharpness and accuracy of the information on the other hand) in order to have a minimal assessment of the evolution of the quality of the water entering into the farm system, under the impact of the aquaculture. More sophisticated analyses can be made if results of non-sophisticated analyses show an evolution of the quality of the water.

Sampling strategy

The fluctuations of parameters in the water may be fast, depending on input of organic matter, but also on natural variations. Often, tendencies in variations may be pointed out only with chronological series. So, it is suggested that sampling be performed at least once or twice a month, depending on several factors, such as (i) the evaluation of waste discharge into the environment, (ii) the nature of the ecosystem (degree of confinement, capacity of water renewal....), (iii) the seasonal variations related to dry and rainy season, (iv) the periods of maximum production on the site, assuming that most of the farmers generally harvest their ponds in the same period of time.

If only one sampling station should be selected in a particular farm system to assess this network, its position as close as possible to the main pumping area (natural or through a series of pumps) is recommended.

2.2.2.2. Data collection guidelines at ecosystem level

2.2.2.2.1. Baseline data at coastal ecosystem level

Baseline data are referred to as any data used on a map for basic positioning. They are usually physical (coastline, elevation) or administrative (town, district contours) and usually necessary to produce all kinds of thematic map for many sectoral applications. This is all the more true in a GIS, where they are used within a data base in connection with, or as a base for, other data. In this sense, their quality in a GIS has to be specifically maintained.

These data sometimes exist under file form, but in most cases, they can only be found under paper form. In this case, they have to be digitised in a consistent way as regards their subsequent use in the GIS.

The sources of data that are usually readily available are the following:

- topographic maps, always available at small scales (1/250000), less frequently at medium scales of 1/50000 or 1/25000. These latter scales are the relevant ones in the case of an application to aquaculture. In Indonesia, Java and Sumatra are totally covered by the 1/50000 series. Their most relevant features are the coastline, the road network, the administrative boundaries, some land use boundaries (inparticular the envelope of aquaculture activities), the toponymy. The map features may be digitised as such but also updated, especially as regards the coastline and land use objects, using satellite images or even any kind of available air photography (see 2.4.5 above),

- marine charts, with essentially the depth lines (both as simple locational data or to be used as input to hydrodynamic modelling), navigation marks and also some conspicuous coastal features,

- land units and soil maps on scale 1/250000 (and also geological maps on same scale), mostly for soil description in relation to upland activities,

- the provincial statistical records published every year, containing a wealth of non-georeferenced data mostly at province level. A part of these data is published under map form (scale 1/500000) every so many years and they could be used, but the uncertainty of their updating makes them not fully reliable.

2.2.2.2.2. Hydrobiological and ecological data

We have previously mentioned that the strategy of the study (sampling location and frequency) has to be adapted to the nature and the specific features of the ecosystem. Thus, the same remark can be done concerning the follow-up of their evolution under the pressure of aquaculture. Parameters to be analysed are those related to the discharge of organic matter and of its « metabolism » (Total Suspended Matter, Particulate Organic matter, Chlorophyll-*a* and pheophytin, sulphate reducing bacteria, cyanobacteria). Same remarks can be done concerning the compromise between the sophistication and the cost of the analyses on the one hand and the sharpness and accuracy of the needed informations on the other hand.

It is to be noticed that preliminary investigations on foraminifera showed that some species could be considered as potential relevant indicators of the degree of confinement and of organic matter accumulation into the ecosystem. As a consequence, the confirmation of this fact would lead to the possession of an integrator of the effects of aquaculture into the ecosystems, which would be less short-term fluctuating than hydrobiological parameters, and apparently easier to analyse (biological determination instead of chemical analyses). Furthermore, long term indicators at the benthic level can also be considered, such as the variation in the specific composition (indices of diversity for benthic populations for example) or in the surface of the biocenoses (seagrass meadows for example). The follow-up of long term ecological benthic indicators allows to integrate, better than short term hydrobiological indicators, the whole variations occurring inside the ecosystem. However, these two kind of indicators cannot answer the same questions. Long term indicators are better integrators of the variations in the characteristics of the environment, short term indicators give faster answer.

2.2.2.2.3. Coastal land use data

It is quite difficult to determine the general impact of coastal activities on the quality of coastal waters. Some relevant factors of influence are listed in **table 79** below. They are of different nature and should be treated in this regard. Generally speaking, the impact of activities other than aquaculture (agriculture, industry, tourism) should be detailed. Relevant data regularly collected by the *kecamatan* (district) administrative units could be used to this end. Some aspects of the degradation and human pressure on these ecosystems can be monitored. Other global indicators may give a hint of the degradation of the coastal ecosystem such as the health of the coastal mangrove or the status of the coastal fisheries (landings statistics).

Table 79. Coastal land use parameters.

	Parameter	Description	Unit	Comments	Collection rate
L1	Tourism	Number of tourists x Number of days spent on tourist site	Inhabitant equivalent		every year
L2	Industry	Factory production	Depending on factory production		every year
L3	Population	Number of inhabitants in each coastal *kecamatan*			every year
L4	Mangrove	number of hectares grubbed up - number of hectares replanted by *kecamatan + surface area remaining from previous year*	Hectares	Data could be aggregated for each aquac. site	every year

Concerning aquaculture itself, the ideal spatial unit in this respect is the village. The village or *desa* is the smallest administrative unit and the one used by *Dinas Perikanan* for their statistics. Development dynamics were shown by increases in the number of farms and surface areas and provided another index for aquaculture pressure. The conversion of rice paddies into *tambaks* is particularly revealing in this regard. The hydraulic developments may also be taken into account for the data base. Global parameters reflecting modern trends such as the number of kilometres of restored canals, and aquaculture surface areas now abandoned for lagoons and filtering, etc. can be defined. These are listed in **table 80**.

If necessary, monitoring parameters used on the village scale could be easily aggregated either at the *kecamatan* level if appropriate or at the ecosystem level, going beyond the administrative boundaries usually applied for synthesis (an ecosystem encompasses several villages or even several districts).

Table 80. Monitoring aquaculture parameters for villages.

	Parameter	Description	Unit	Comments	Collection rate
V1	Aquaculture Pressure	Village's production, trends, pond acreage,	Tons		*every cycle or every year)*
V2	Intensific. in surface areas	Aquaculture surface areas	Ha	Indicates activity's development dynamics	every year
V3	Conversions	Rice paddy surfaces converted into *tambaks*	Ha	Figures difficult to obtain	every year
V4	Overall yield	V1 / V2	tons / ha	Overall efficiency index for activity per village	every cycle (same as V1)
V5	Hydraulic improvement	Number of kilometres of canals restored to improve aquaculture water management	Km	Indicator of better environmental quality in production area	every year
V6	Aquaculture conversions	Number of farms which have converted from shrimp farming to fish farming	n° of farms	An interesting indicator representing rising awareness of degradation amongst the farmers themselves	every year

2.2.2.2.4. Other data: watershed land use

At the ecosystem level, the influence on the coastal zone has to be sought far upland. Each watershed has its own characteristics conditioning the potential pollutant flow reaching the coastal zone at its outlet. Major watershed parametres aare summarized in **table 81**. Agricultural pollution comes from diverse sources. Direct links can be drawn between livestock and potential pollution in terms of farm effluents, depending on the species and type of farm (for instance, a poultry farm will most likely pollute less than an intensive poultry production plant). Crops create several types of pollution, such as organic or chemical fertilisers and pesticides. Only homogeneous crops requiring large quantities of these products would be considered in a first approach.

Some other factors can be monitored, such as deforestation of watershed slopes, most critical in terms of erosion and areas where land is cultivated, then left fallow.

Table 81. Watershed parameters.

	Parameter	Description	Unit	Comments	Collection rate
BV1	Livestock farming	Livestock reared using semi-industrial or industrial methods	heads	Data from *kecamatan* concerned is aggregated; type of stock farming is distinguished (poultry, pig, goat, cattle)	Every year
BV2	All large annual crops Manioc,Maïze, sweat potatoes	Large surface area cultivated using consistent practices *	ha	Aggregation of data from *kecamatan* concerned	Every year
BV3	Urea	Quantity of urea added to all crops over the watershed	ha	Aggregation of data from *kecamatan* concerned Data recorded in controlled market framework	Every year
BV4	TSP	Quantity of TSP added to all crops over the watershed		Aggregation of data from *kecamatan* concerned Data recorded in controlled market framework	Every year
BV5	Coffee, Hevea, Sugar cane Pineapple	Large plantation surface areas cultivated on low and middle mountain slopes, using consistent practices*	ha	Aggregation of data from *kecamatan* concerned	Every year
BV6	Deforestation	Wooded surface area grubbed up - replanted surface area over the watershed	ha	Aggregation of data from *kecamatan* concerned	every year
BV7	Land left fallow	Watershed surface areas left fallow after cultivation	ha	Aggregation of data from *kecamatan* concerned	every year
BV8	Industries	Production from each "polluting" factory over the watershed	depending on factory production	More localised pollution: data on watershed scale, but maintaining each factory unit	every year
BV9	Urban areas	Populations of highly populated areas over the watershed	Number of inhabitants	More localised pollution: data on watershed scale, but maintaining each factory unit	every year

Consistent practices of cultivation are those considered to "produce" the same quantities of pollutants per surface area unit: the surface area farmed will give good indication or the overall evolution of pollution sources thus monitored.

2.2.2.3. Suggestions for data collection in Indonesia

It is estimated that the higher the administrative level, the less reliable the available data will be. Above a given level, some data even becomes inaccessible. These constraints are such that some university researchers no longer use official data, but prefer to take their own samples, in spite of the high costs and efforts required.

The above-mentioned descriptors, when recognised to be relevant for inclusion into the data base, should be monitored by a cross-disciplinary administrative team at Bandar Lampung, which would gather detailed data per *desa* when appropriate but rather per *kecamatan*, with the further possibility to aggregate them in a GIS for coastal ecosystems and watersheds if required. **Figure 63**, p. 164, shows the coastal *kecamatan* concerned by the study. Obviously *kecamatan* are sizeable and relevant geographical objects as regards expressing the influence of land use on the neighbouring coastal waters

The data base provides a framework in which to analyse the coastal area environment using existing data. It could be easily implemented, with low cost operational monitoring. The *Biro Lingkungan* (Environment Office) in the Governor's Office, or the *Bappeda* administration in charge of planning and provincial programmes could be given responsibility for data base monitoring and management. Data per sector of activity could be obtained, either routinely or directly in the field or from the *kecamatan*, thus respecting the administration hierarchy while attempting to limit defects by more direct collection at the local level. This could improve communications and working relationships between staff of different territorial levels.

Concerning data derived from remote sensing, if local knowledge cannot be found among the administrations and universities, support has to be sought from instances in Jakarta, BPPT for instance, who are able to provide assistance in acquiring and processing some types of imagery (from aerial photography to satellite images) according to their own experience and/or the experience gained in this project.

2.2.3. Towards management tools within a GIS

2.2.3.1. Why a GIS for assessing environmental impact on aquaculture activity ?

The general objective of the project is to understand the efficiency of the aquaculture system within its global environment. This implies to be able to understand impacts of various kinds, those generated outside the system (referred to as "externalities") and those resulting from the activity itself. Only then will it be feasible to give hints about the sustainability of the activity. However, it is difficult to sort out the real causes. What is the share of the shrimp farming intensification, that results in increased amounts of waste rejected into coastal waters, and the upland activities, which in many ways pollute rivers running off into coastal waters ?

Rather than dealing in an analytical way, still far from reach at present, another way is to try and monitor the health of the coastal waters, natural receptacle of all sources of pollution and try to relate its evolution with major changes occurring in a) the aquaculture sphere, b) land use and activities other than aquaculture in the coastal *kecamatan*, c) the upland territories, the influence of which could be apprehended through sampling at river mouths.

This could be performed through correlations between global indicators of the causes and global indicators of the aquaculture efficiency. Yet, to have a chance to perceive any relationship between efficiency and the environment, the effects of pond management have to be filtered. Obviously, some farmers, due to their skills, will maintain some efficiency even in adverse conditions, while others will collapse. So, the preliminary task is to group farms a) according to their stocking density, b) to classify between « good »and « bad » management (which still remains to be defined...) and then deal with each group separately. The time span will have to be as long as possible (certainly over five years), so that high frequency variations may be filtered out. This means being able to store reliable data in a long term perspective.

The task of the GIS structure definition is to recapitulate all parameters listed above, and for each of them to see which geographical object best expresses them, what is its status (availability, scale, updating, etc.) and, every time it is possible, provide a logical link between related objects.

2.2.3.2. The GIS structure

As mentioned above there are many data involved for environmental impact assessment. The data should be structured in the database so that the storing and retrieval for analysis purposes can be done easily and effectively. For spatial data handling with computer, the data should be structured so that a machine can interpret and process them. Data modelling techniques are common methodologies broadly used in database design. Various levels of data modelling will be used in this study, which are explained in the following:

- **Conceptual data modelling**: The goal is to create a conceptual scheme for a database using the formal approach Entity Relationship (ER) modelling. A conceptual scheme is a concise description of users' data requirements which includes a detailed description of data types, relationships and constraints. This high conceptual scheme can be used to communicate with non-technical users. Also it can be used to make sure that all users' data requirements are met and generate no conflict. The designer can concentrate on specifying the properties of data without being concerned with storage details.

- **Logical data modelling**: The next step is transforming the ER model into commercial DBMS. The results is a conceptual schema for implementation of data model of the DBMS. The relational data model, which organises data in tables, is selected to implement the data model.

- **Physical data modelling**: The last step is specifying the internal storage structure and file organisation of the database.

* *The conceptual data model*

The basic concept of the ER model is entity, attribute (properties) and relationship. An entity is a thing (object, concept) which can be uniquely identified, for example a pond, a river, etc. It could be a spatial or non-spatial entity. An entity has properties or attributes which describe it in detail, for example the attributes of a pond are pond number, pond area, pond age, etc.. A relationship is an association between two (or more) entities. Based on the data that have been collected above, the entities and their attributes can be identified as is presented in **table 82.**

Table 82. Entities and their attributes.

No	Entity name	Attributes
I. Spatial entity		
1	Pond	Pond-id, ...
2	River	River-id, length, ...
3	River outlet	River-id, ...
4	Road	Road-id, length, ..
5	Coastline	Coastline-id, length, tendency to erosion, ..
6	Village boundary	Village-id, village-name, area
7	Watershed	Watershed-id, area
8	Landcover	Landcover-id, landcover class
9	Satellite image	Pixel value
10	Coastal ecosystem	Ce-id, area, population, industry, mangrove, tourism
II. Non-spatial entity		
1	Pond environment	Pond-id, village-id, distshore, distrvr
2	Pond management	Pond-id, stocking, surfaces, pondages, fcr, sr, production, renewal
3	Village statistic	Village-id, district-id, pond area, production, household

The relationships between entities are depicted in **figure 94**. Some entities, such as a satellite image, are not connected to other entities. This situation does not show that those entities do not have relationships, basically they already have an implicit relationship with others through their geometrical attributes, i.e. X and Y coordinates, which will allow later operations such as « spatial joints ».

For example, the entity « pond », if relevant to impact assessment purposes, is described through its relationships with the outside world, which may be:

- M: 1 (many to one) to Village: many ponds belong to one village.
- M: 1 to River outlet: many pond have distance to river.
- 1: M to Pond management: one pond has a lot of pond management information, this is due to time series of pond management information.
- 1: 1 to Coastline: one pond has only one distance to the coastline.

Other examples of relationships are:

- 1: 1 relationship between river outlet and river: one river has one outlet.
- M: 1 relationship between River and Watershed: one watershed can have many river segments.
- M: 1 relationship between Pond and Coastal ecosystem.

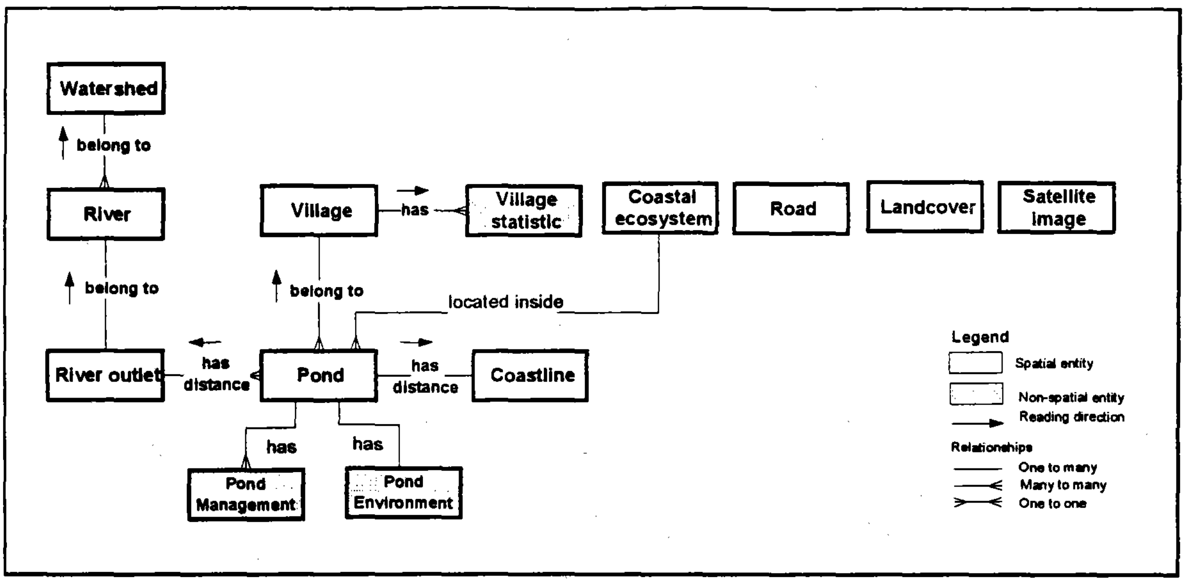


Figure 94. Data Model.

*** The logical data model**

The next step is to transform the conceptual model into a relational data model. The entities which have relationships of the kind « many to many » have to be normalised. The result of normalisation can be shown in two forms i.e. the ERD (**figure 95**) and the Skeleton table (**table 83**). **Figure 95** illustrates the ERD logical data model. Some entities are not included in the diagram, because they do not have direct links to these entities. A square box represents a table with its name appearing on top, the underlined word is the key identifier and the others are secondary identifiers for links between two entities. As entities « pond » and « pond environment » have one to one relationship normalised by forming only one table, all attributes of pond environment belong to pond entity.

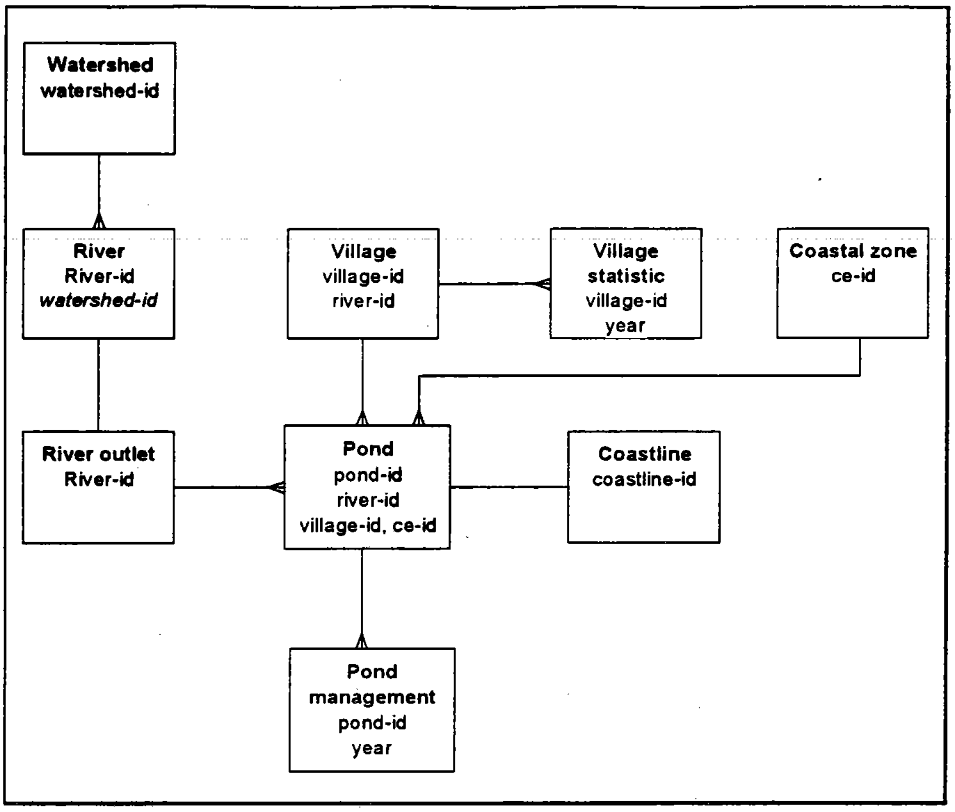


Figure 95. ERD logical data model.

Table 83. Table structure.

No	Entity	Object type	Feature table	Related table
1	Pond	Point	**Pond** (….., pond-id, distance to river, distance to shore, distance class, *river-id*)	**Pond management** (pond-id, *village-id*, surface area, production, fcr, sr, stocking density, pond ages, fcr class, farming system, pond ages class)
2	River	Line	**River** (river-id, length, …)	
3	River outlet	Point	**River outlet** (river-id, …)	
4	Road	Line	**Road** (road-id, length, ..)	
5	Coastline	Line	**Coastline** (coastline-id, length, ..)	
6	Village boundary	Polygon	**Village** (village-id, village-name, area, …)	**Village statistic** (village-id, district-id, regency-id, pond area, production, household, ..)
7	Watershed	Polygon	**Watershed** (watershed-id, area, …)	
8	Landcover	Polygon	**Landcover** (landcover-id, landcover-class, area, ..)	
9	Satellite image	Image	**Satellite image** (pixel value, ..)	
10	Coastal ecosystem	Polygon	**Coastal ecosystem** (ce-id, area, population, industry, mangrove, tourism	

* *The physical data model*

The next step is transform the logical model into the Arc/Info data structure i.e. a coverage for spatial data and tables (INFO or Dbase) for alphanumeric data. Examples of the results of the transformation into the Arc/Info data structure are presented there after:

- Village boundary
  Coverage name : VILLAGE
  Coverage type : Polygon
  Table structure :

Field	Description	Width	Type
AREA	Area provided by the software	Default	N
PERIMETER	Perimeter provided by the software	Default	N
VILLAGE_	Internal arc/info identifier	Default	N
VILLAGE_ID	Village identification number	8	N
VILLAGE_NA	Village name	20	C

- Village statistic
  Table name : STAT_[YY].DBF (YY replace by year of statistical data)
  Table structure :

Field	Description	Width	Type
Village-id	Village identification: 2301 = Margasari 2302 = Srimino Sari 2303 = M. Gading Mas 2304 = Bandar Negeri 2305 = Karya Makmur 2306 = Karya Tani 2401 = Pasir Sakti 2403 = Mulyo Sari 2402 = Purworejo 2404 = Labuhan Ratu 3101 = Bandar Agung 3102 = Berundung 3201 = Pematang Pasir 3301 = Kalianda 3302 = Merak Belantung	8	N
Tot_area	Pond total area (ha)	10	N
Production	Total shrimp production (ton)	10	N
Household	Number of family involved (people)	10	N

- Pond position
  Coverage name : POND
  Coverage type : point
  Table structure :

Field	Description	Width	Type
AREA	Area provided by the software	Default	N
PERIMETER	Perimeter provided by the software	Default	N
POND_	Internal arc/info identifier	Default	N
POND_ID	Pond identification number	Default	N
X_Coord	Pond X coordinates	Default	
Y_Coord	Pond Y coordinate	Default	
DISTSHR	Distance to shore (m)	10	N
DISTRVR	Distance to river (m)	10	N
CLASS1	Distance to shore class: 1. < 0.5 km, 2. 0.5 – 1 km, and 3. > 1 km	4	N

- Pond management
  Table name : RES[YY]_[Crop_No].DBF
  Table structure :

Field	Description	Width	Type
Pond_id	Pond identification number	8	N
Village_id	Village identification number	8	N
Surface	Pond surface area (ha)	10	N
Pondage	Pond ages (years)	8	N
Stocking	Stocking density (fry/hectares)	10	N
Production	Shrimp production (kg/ha)	10	N
Fcrcls	FCR class: 1. < 1, 2. 1 – 1.5, 3. > 1.5	4	N
Technique	Farm management system: 1. Traditional, 2. Semi intensive, 3. Intensive	4	N
Agecls	Pond ages class: 1. <= 5 years, 2. > 5 years	4	N

2.2.3.3. GIS Implementation

ARC/INFO and ArcView are used to implement the design. ARC/INFO is a commercial GIS software, which has capability for data capture, management, manipulation, analysis and presentation. The system is widely used in Indonesia and running on many platforms and under operating systems such as PC with DOS or Windows environment, workstation with Unix or VMS environment, etc. ArcView provides a graphical user interface (GUI) for assessing the data. It also provides a development tool, i.e. Avenue, for developing a GUI and customising it, whereby providing non-technical users a friendly environment to easily access, manipulate and review the database.

A Personal Computer with Windows 95 operating system is selected to implement the database. ArcView 2.1 for Windows and PC Arc/Info for DOS are the selected software for implementation. Arc/Info is used for digitising, editing and updating spatial data and ArcView is used for visualisation, querying and printing the data already stored in the database. A user interface is also developed by Avenue to create menus to visualise, query and print maps.

Figure 96 illustrates the main menu of the ArcView software. Basically there are three types of menus: on top are the Pulldown menu, the Pushbutton menu and Tool button menu. Each menu has specific tasks to perform. The data is displayed in the View document that contains table of contents that have the list of data and visualisation of the data. In the window are displayed Pond sample, river outlet, river, coastline and satellite image. Using the menu already customised for the database, the user can explore the contents of database for visualisation or analysis purposes.

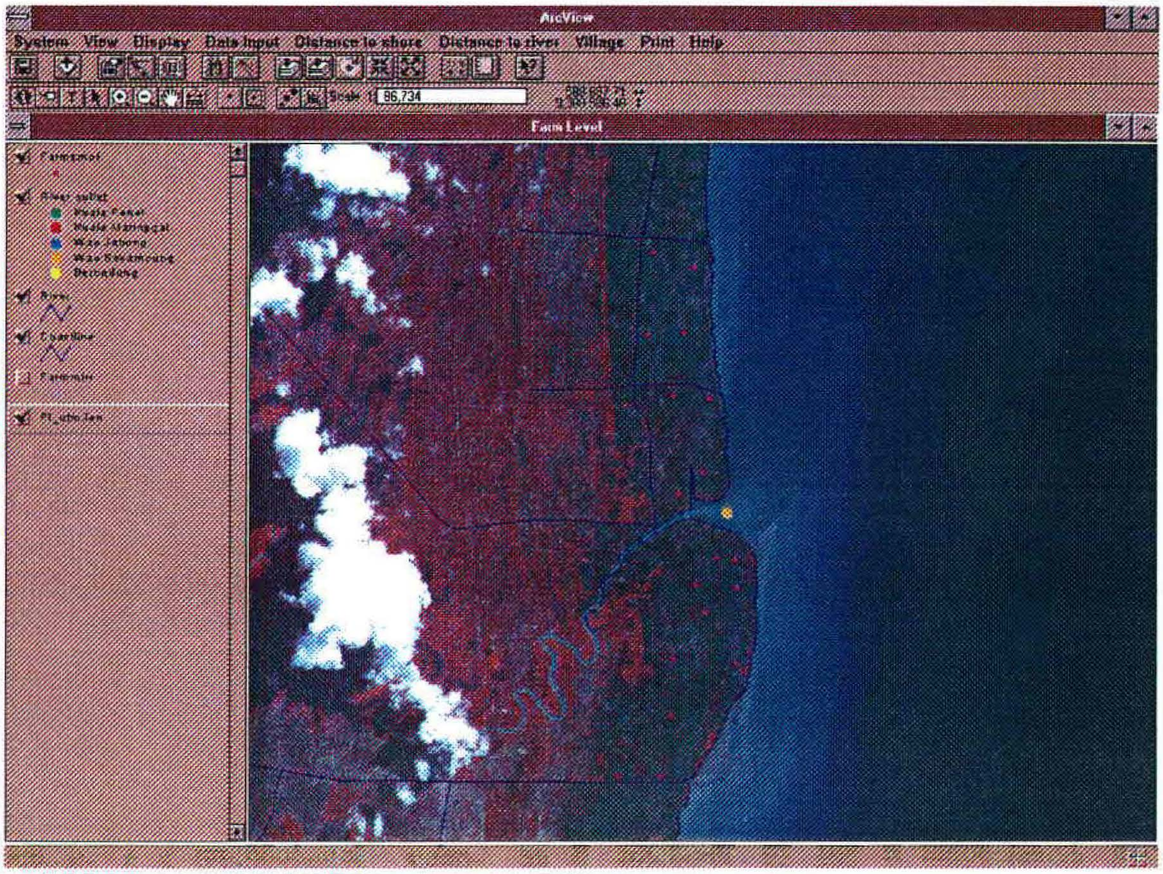


Figure 96. System interface.

2.2.4. Synthesis and preliminary results of GIS for aquaculture management

The interesting fact about the East Lampung coast is the way intensification occurs and whether it is bound to be sustainable on the long term. It may be a spatial intensification (more ponds) or a rearing intensification (more animals per surface unit) or any combination of the two. **Table 84** below is an example of 1995 statistical data as collected by the fisheries services in all villages of the Lampung province. They are used below in the GIS to show the production status in 1995 under a spatial point of view. Similar tables are available since 1992, but their reliability decreases with their age. In spite of their questionable quality, they have also been used to give an idea of the trend over the four year span.

Table 84. Village production statistics for 1995.

Sumber: DPT.I (sample of farmers)

Kabupaten	Kecamatan	Village	1995 Area (ha)	Production per year (ton)	Seed per year (10E06 PL)	Seed / ha / crop (1000 PL/ha)	Production / ha / crop (kg/ha)	Efficiency (kg/1000 seeds)
Lampung Tengah	Labuhan Maringgai	Marga Sari	218,7	231,2	21,8	50	529	10,6
		Sriminosari	285,0	491,1	27,0	47	862	18,2
		Muara Gading Mas	369,2	326,6	36,9	50	442	8,9
		Bandar Negeri	600,0	572,4	55,0	46	477	10,4
		Karya Makmur	179,5	140,5	14,2	40	391	9,9
		Karya Tani	310,0	259,5	26,2	42	419	9,9
		Total Kecamatan	**1962,4**	**2021,3**	**181,1**	**46**	**515**	**11,2**
	Jabung	Pasir Sakti	415,0	124,5	24,8	30	150	5,0
		Purworejo	472,0	179,3	25,9	27	190	6,9
		Mulyosari	456,0	173,3	24,0	26	190	7,2
		Labuhan Ratu	324,0	126,4	17,8	27	195	7,1
		Total Kecamatan	**1667,0**	**603,5**	**92,5**	**28**	**181**	**6,5**
		Total Kabupaten	**3629,4**	**2624,8**	**273,6**	**38**	**362**	**9,6**
Lampung Selatan	Palas	Bandar Agung	537,0	204,0	31,8	30	190	6,4
		Total Kecamatan	**537,0**	**204,0**	**31,8**	**30**	**190**	**6,4**
	Penengahan	Berundung	686,0	432,5	61,2	45	315	7,1
		Pematang Pasik	124,0	40,5	29,7	120	163	1,4
		Sumber Nadi	80,0	48,0	11,0	69	300	4,4
		Tridarmayoga	10,0	5,3	0,5	25	265	10,6
		Ruguk	60,0	90,0	4,2	35	750	21,4
non include Cukuh Balak		Sumur	105,0	136,5	7,3	35	650	18,7
		Bakauheni	30,0	72,0	7,5	125	1200	9,6
		Total Kecamatan	**1095,0**	**824,8**	**121,4**	**55**	**377**	**6,8**
	Kalianda	Kalianda	75,0	112,5	21,3	142	750	5,3
		Merak Belantung	15,0	120,5	5,7	190	4017	21,1
		Total Kecamatan	**90,0**	**233,0**	**27,0**	**150**	**1294**	**8,6**
	Kota Agung	Kagungan	26,0	105,5	3,5	67	2029	30,3
		Total Kecamatan	**26,0**	**105,5**	**3,5**	**67**	**2029**	**30,3**
	Wonosobo	Karang Anyar	110,0	236,0	27,5	125	1073	8,6
		Total Kecamatan	**110,0**	**236,0**	**27,5**	**125**	**1073**	**8,6**

2.2.4.1. Production and intensification based on village data

Production in **table 84** is the total weight produced per year per village. Intensification is usually qualified by the stocking density according to the following classes:

- 0 < stocking < 40000: traditional (1)
- 40000 < stocking < 100000: semi-intensive (2)
- 100000 < stocking < 500000: intensive (3)

As we had no figures for stocking density on a village basis, we have used the production per hectare per crop (PHC) as a first approximation of the level of rearing intensification (it differs from the latter by the influence of the survival rate).

Besides, **table 85** gives the rate of surface intensification per village over the period 1992-1995, computed from Dinas Perikanan figures. Another interesting figure is the efficiency, expressed as the production in kilograms per thousand seeds. This variable, taking into account the survival rate, gives the best vison of performance.

Table 85: surface intensification between 1992 and 1995 (from Dinas Perikanan)

VILLAGE	FARM-SURF 92 (ha)	FARM-SURF95 (ha)	Ratio 95/92
Margasari	175	219	1.25
Sriminosari	300	285	0.95
Muara Gading Mas	350	369	1.05
Bandar Negeri	560	600	1.07
Karya Makmur	315	180	0.57
Karya Tani	400	310	0.77
Pasir Sakti	182	415	2.28
Mulyosari	271	456	1.68
Purworejo	360	472	1.31
Labuhan Ratu	173	324	1.87
Bandar Agung	566	537	0.95
Berundung	379	686	1.81
Merak Belantung	8	15	1.88
Kalianda	52	75	1.44
Pematang Pasik	123	124	1.00
Sumber Nadi	70	80	1.14
Tridarmayoga	0	10	-
Ruguk	0	60	-
Sumur	0	105	-
Bakauheni	0	30	-

Figure 97 below displays 20 village in six kecamatan concerned by the study, i.e. Labuhan Meringgai, Jabung, Palas and Penengahan on the East coast (referred to as Pantai Timur herebelow), Kalianda on the West coast. Production data from 1992 to 1995 have been processed in order to try and understand its spatial trends. Note that for the four southernmost villages of Penengahan, only 1995 data were available. The pie charts of **figure 97a** should be read the following way (i) the size of the pie is proportional to the PHC in 1995 (ii) PHC along the four years turns anti-clockwise: 1992 is blue, 1993 green, 1994 orange and 1995 red.

Several striking facts can be noted: in 1995, PHC is quite good in the North and South of the eastern coast (0.4 to 0.9 tons/ha/crop) but reaches a minimum (hardly 0.2 tons/ha/crop) around the river Sekampung mouth. At the same time, the intensification trend over the four years, high in the North, suddenly drops in Pasir Sakti and is getting better again in Sumber Nadi. Is there a socio-economical reason, such as common village behaviour for instance? According to the socio-economic study, it is unlikely so, since the way historical settlement occurred along this coast is rather homogeneous .

The reason is more likely to be an environmental one and should be sought looking at the general hydrobiological situation of Pantai Timur, a hint of which is given by the Spot image on **figure 98a**. In spite of the prevailing southward transit and the presence, some 80 km to the North, of the huge Dipasena shrimp complex, it may be that northern Pantai Timur is protected by the Way Kambas National Park acting as a buffer. Together with little river influence, this would explain the health of this region. In central Pantai Timur, (around

Labuhan Ratu), the Sekampung river generates heavy runoff of high laden waters detrimental to the surrounding ponds. This effect is diluted southward, as is denoted by the image. In Penengahan, performance increases again, with intrusions of clear water from the Sunda straight and water quality probably comparable to that of Kalianda.

On the West coast, Merak Belantung shows a remarkable (and expectable) stability in an altogether high performance (around 4 tons/ha/crop), with a slight increase in 1995. Conversely, Kalianda has been little efficient over the period, with even a slight drop in performance in 1995, which remains to be explained.

Secondly, we can give a look at surface intensification ratios over the 1992-1995 period, illustrated by **figure 97b**, itself based on DP data of **table 85**. It is interesting to compare these ratios to those obtained through the processing of satellite imagery shown in **table 74** repeated herebelow (see text on page 201). Pond area conversion figures rom 1991 to 1995 were derived from imagery interpretation and ratioed to the 1995 DP figures. There is a good overall fit between the ratios in both tables, except for strong discrepancies for Muara Gading Mas and Karya Tani. The explanation might be the difference in dates, i.e. 1991 for the Landsat image and 1992 for DP data.

Table 74: surfaces of paddy to pond culture conversion (from satellite imagery)

Village	Pond area conv. 91-95 (ha)	Pond area1995 (ha)	Ratio 95/91
Margasari	43	219	1.24
Srimino sari	143	285	2.00
M. Gading Mas	165	369	1.80
Bandar Negeri	82	600	1.16
Karya Makmur	14	179	1.08
Karya Tani	246	310	4.84
Pasir Sakti	204	415	1.96
Mulyosari	154	456	1.49
Purworejo	73	472	1.18
Labuhan Ratu	113	324	1.53
TOTAL	1237	3629	

It appears that most villages had an increase in pond surfaces. Out of a total of 3600 hectares of ponds in 1995, 1200 have been gained from paddy over the last four years. While most villages experienced surface intensification, some of them also experienced rearing intensification, although there does not seem to be a relation between the two movements. It is clear that in a case where the activity was previously very traditional, two scenarii may be found a) if the intensification concerns surface, then it probably is just an extension of traditional ponds with no noticeable gains in productivity, b) if there is rearing intensification, there may be a gain in productivity accompanied by a loss in reared surface.

The distribution of efficiency (**figure 97c**) further confirms the previous findings, with a strong minimum around river Sekampung. Yet this should confronted with data on the type of rearing sytem (i.e. stocking density), which are only available for network farms. This is the topic of the next section herebelow.

Finally, of all Pantai Timur villages, Sri Minosari displays the best situation: high overall production, in semi-intensive to intensive conditions (almost 1 ton per hectare per crop) and a very high efficiency of 18.2 kg/1000 seed. Two hypothesis may be formulated a) either the turbidity plume clearly seen on images around Way Penet point is not detrimental to water quality, b) or in spite of it, the intensive and semi-intensive methods of these particular farms methods are able to maintain very good productivity methods.

In order to check the relative incidences on efficiency of the environment and of the rearing techniques, more efforts should be devoted at the same time to environmental and zootechnical surveys. In a second step, we have given a look the farm data as regards the quality of their management. Unfortunately, as has been mentioned otherwise in this report, 1996 farm data is not fully reliable due to bias in the choice of sample farms. There has been a tendancy by the survey officers to examine the most performing units.

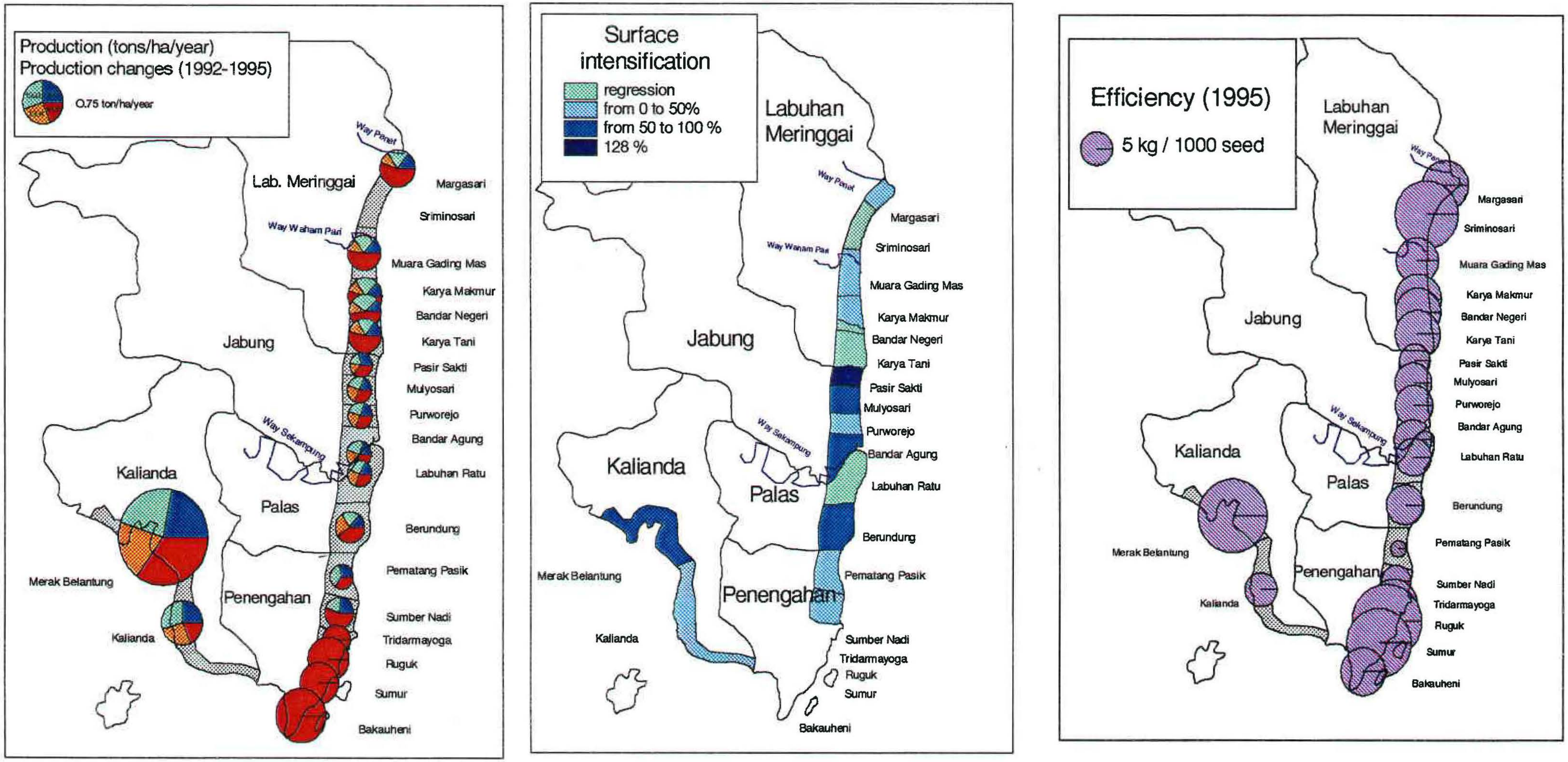


Figure 97. (a) 1995 production and trend 1992-1995, (b) surface intensification 1992-1995, c) efficiency in 1995.

2.2.4.2. Efficiency measured from farm statistics

In view of the above results, data collected in the sample farms can be examined. The sample includes 77 farms scattered along Pantai Timur as well as 5 farm in the Kalianda district. The Pantai Timur farm network is shown on **figure 98a**, where « d », the distance to the shore has been computed for each farm and a colour code given accordingly (magenta if d>800 metres, orange if d< 800 metres). An example of the data collected during the 1995 field is shown on **table 86**.

Table 86. Example of farm management data (1995 survey on 82 farms).

Farm id	Crop no	Year	Stocking	Fcr	Sr	Activity
1	1	1994	305000,00	1,38	81,64	3
1	2	1994	305000,00	1,38	81,64	3
1	1	1995	305000,00	1,38	81,64	3
1	2	1995	305000,00	1,38	81,64	3
2	2	1994	90000,00	1,00	16,67	2
2	1	1995	110000,00	1,00	20,45	3
2	2	1995	120000,00	1,00	31,25	3
3	1	1994	50000,00	0,90	56,00	2

Farm_id varies sequentially from 1 to 82, each record in the table illustrates a crop and is therefore a triplet (farm, crop_n°, year). Note that there may be up to three crops per year. Stocking qualifies the number of seed per hectare, hence the rearing type, with the following classes:

- 0 < stocking < 40000: traditional (1)
- 40000 < stocking < 100000: semi-intensive (2)
- 100000 < stocking < 500000 : intensive (3).

FRC (food conversion ratio) and SR (survival rate) are two zootechnical indicators representative to a certain extent of the rearing efficiency. Both have been surveyed for each crop since 1992. Unfortunately, FCRs are not properly declared by the farmers, leading to values far too low. The expectable FCRs should be between 1.5 at lowest to anywhere around 3 to 4. Therefore, all FCR below 1 have been discarded. The remaining FCR values (28 samples) were not in sufficient number to be processed. SR values appeared more reliable.

A **first approach** consisted in taking a look at the survival rate per rearing activity. This appears on **figure 98b** where, among 57 farms, 37 are traditional (green) 10 semi-intensive (blue) and 10 intensive (red). For better readibility, the red dots have been displaced seaward. It is noteworthy that all intensive and semi-intensive farms are grouped in the very north of Pantai Timur. The network unfortunately did not reach the southern villages, but it is likely that the tendancy there is also towards intensification.

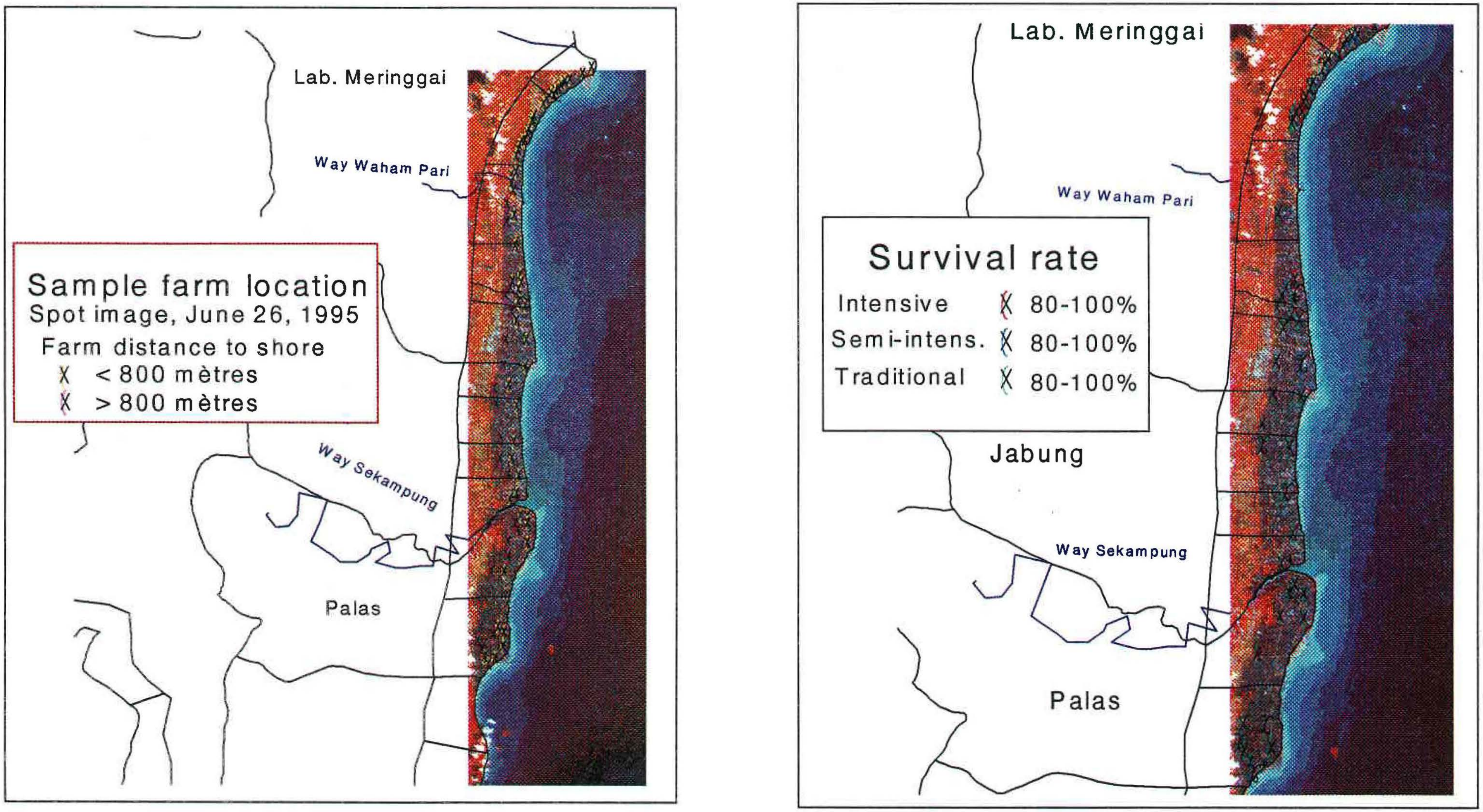


Figure 98. a) location of 77 Pantai Timur sample farms (1996 survey) with farm distance to shore, b) survival rate according to rearing type.

Another approach takes into account farms distances to the shoreline. As this distance varies from 50 m to 1500 m, a threshold has been chosen as 800 metres (**figure 98b**). Farms located further than 800 metres away from the shore are 95 % traditional. At a shorter distance they are more evenly distributed in the three classes (**table 87**). Among traditional farms, there is a SR decrease of 6 % for inland farms. Although very small a difference, it may confirm the following hypothesis: water circulation in inlet canals from the sea to the pond being gravitary (especially in the traditional system), when it has to travel as far as three kilometres, there may be a degradation of its quality detrimental to rearing conditions.

More striking is the fact that, among all farms located close to the shore, there is more success in terms of survival in the traditional system (58 %) than in semi and intensive ones (respectively 49 % and 46 %). This may confirm some findings of the socio-economic work stating that the conversion from traditional to semi-intensive is often a failure for farmers who do not have enough knowledge to cope with its consequences. However, this is also in contradiction with the above efficiency results...

Table 87. Survival rate as a function of distance to the shore for 57 farms.

	Traditional	Semi-intensive	Intensive
Number of farms Disshore > 800 m	15	1	1
SR	52 (21)	NA	NA
Number of farms Disshore < 800 m	22	9	9
SR	58 (25)	49 (24)	46 (25)

2.2.4.3. Conclusion

To conclude with this analysis, Sri Minosari in the North is top ranking in terms of efficiency and performance, with all farms located close to the shore; obviously rearing intensification has being a success there. At the other end of the scale, in the central part around river Sekampung, high shrimp revenue lead people to reclaim more and more land to aquaculture but they remain in the traditional system. Even land located at the shore is not intensified, for reasons most likely environmental.

A lot more work remains to be done by examining those figures more in depth and trying to relate efficiency records to environmental factors, on a village basis for production, on a farm basis for zootechnical parametres. These results should be consolidated on an extended and more reliable sample.

The distribution of coastal water quality alongshore is still unknown, even though guesses may be formulated when looking at turbidity patterns on satellite images, especially around the Sekampung river mouth. Only a more detailed hydrobiological, by running a few transects from north to south study could lead to spatially rank this quality.

The farm sample network also needs to be re-examined on the basis of these findings, with the aim to better understand the local success of intensification. If the sea water quality entering inlet canals could be better monitored, the way it is processed within the aquacultural system could then lead to the establishment of an index of "farm water quality" and correlations with the efficiency could be drawn.

Références

BPS, 1992. *Lampung in figures, 1991/1992*. Regional Development Planning Board and Statistical Office of Lampung Province, Indonesia.

Bappeda, 1993. *Laporan Neraca sumberdaya alam Propinsi Daerah Tingkat I Lampung dan Kabupaten Daerah Tingkat II Lampung Tengah tahun 1992/1993*. Bappeda Tingkat I Lampung, Indonesia.

Dekker A. G., H.J. Hoogenboom, P. Moen, 1994. Implementation of high resolution airborne remote sensing in inland water management. Proceedings of an *Earsel workshop on remote sensing and GIS for coastal zone management*, ed. R. Allewijn, Rijkswaterstaat, 2600 GA Delft, the Netherlands, p. 94-103.

Ekstrand S., 1992. Landsat TM based quantification of chlorophyll-a during algae blooms in coastal waters. *Int. J. remote Sensing*, vol. 13, n° 10, 1913-1926.

Guelorget O., J.L. M.Martin, A. Lefebvre, C. Courties, J.P. Perthuisot, J. Fuchs, M. Suastika, Open sea paralic ecosystems south of Java Sea. Environmental approach by flow-cytometry. *Journal of Coastal Research* (in press).

Howe, 1984. *Data analysis for database design. Second edition*. Howard Arnold, London.

Hawryszkiewycz I.T., 1994. *Introduction o system analysis and design, 3rd edition*. Prentice Hall Australia.

Kapetsky J.M. and C. Travaglia, 1995. Geographical Information Systems and Remote Sensing: an Overview aof their Present and Potential Applications in Aquaculture. In Aquaculture Towards the 21sst Century. Proceedings of the Infofish-Aquatec '94 conference, Colombo, Sri Lanka, 29-31 Aug. 1994, p. 187-208.

King D.J., 1995. Airborne multispectral digital camera and video sensors: a critical review of system designs and applications. *Canadian Journal of Remote Sensing*, Vol. 21, n° 3, p. 245-273.

King D.J. and J. Vlcek. 1990. Development of a multispectral video system and its application in forestry. *Canadian Journal of Remote Sensing*, Vol. 16, p. 15-22.

Laurini, Robert and Thompson, Derek, 1996. The A.P.I.C. Series Number 37: *Fundamental of spatial information system*. Academic Press, London.

Lavery P., C. Pattiaratchi, A. Wyllie, P. Hick, 1993. Water quality monitoring in estuarine waters using the Landsat Thematic Mapper. *Remote sensing of Environment*, 46, p. 268-280.

Loubersac L. *et al.*, 1991. General Inventory of Shrimp Aquaculture Potential in New Caledonia. In: Applications of Remote Sensing in Asia and Oceania. Published by Asian Association on Remote Sensing, Geocarto International Centre, GPO BOX 4122, HONG KONG.

Nichol J.E., 1993. Remote Sensing of Water Quality in the Singapore-Johore-Riau Growth Triangle. *Remote Sens. Environ.* 43: 139-148.

Populus J. and D. Lantieri, 1991. Use of High Resolution Satellite Data for Coastal Fisheries. FAO RSC Series N°58. High resolution satellite data series N°5.

Populus J. *et al.*, 1995. Remote sensing as a tool for diagnostic of water quality in Indonesian seas. *Ocean and Coastal Management*, Vol.27, N° 3, p. 197-215.

Populus J., A. Wibowo, J. Prou, Use of airborne remote sensing data for the management of coastal aquaculture. *Second International Airborne Remote Sensing Conference and Exhibition*, San Francisco, 24-27 June 1996.

Tanré D., C. Deroo, J.J. Morcrette, J. Perbos, P.Y. Deschamps, 1988. Effets atmosphériques en télédétection. Logiciel de simulation du signal satellitaire dans le système solaire. *Proceedings of the 4th international colloquium on spectral signature of objects in remote sensing.* Aussois, France, 18-22 Jan. 1988, ESA SP-287, April 1988.

Tassan S., 1993. An improved in-water algorithm for the determination of chlorophyll and suspended sediment concentration from Thematic Mapper in coastal waters. *Int. J. Remote Sensing*, vol. 14, n° 6, p. 1221-1229.

Whitlock C.H., C.Y. Kuo, S. LeCroy, 1982. Criteria for the Use of Regression Analysis for Remote Sensing of Sediments and Pollutants, *Remote Sensing of Environment*, 12: 151-168.

Wibowo A., W. Hastuti, J. Populus, A. Karsidi, 1993. The application of remote sensing and GIS technology for monitoring and site selection of aquaculture ponds on coastal areas. Presented at *National Conference on ERS1, Landsat and SPOT*, Jakarta, Nov. 1993, ed. by BPPT, Jalan Thamrin 8, Jakarta.

CHAPTER 3 - GENERAL CONCLUSIONS

Authors: *J. Fuchs* *Ifremer/Paris*
J.L. M.Martin *Crema/L'Houmeau*
J. Populus *Ifremer/DEL/AO*

With a total annual production in excess of 900,000 metric tons, shrimp farming has become a vital economic activity in many countries of Asia, South America and the Pacific region. The shrimp farming boom of the last 10 years led to intense exploitation of many coastal regions and it often developed without any controls and limits on its expansion. This rapid development had a drastic impact on the environment in most of the countries concerned and led to severe conflicts with other users. In some extreme cases, where the environmental conditions were not suitable, a total collapse on a very large scale was observed. The investors argue that these negative effects are nevertheless offset by a positive effort to vitalise poor rural areas, the numerous jobs created, etc. in countries such as Thailand or Indonesia, where shrimp products have become leading exports.

These positive and negative effects show that aquaculture, and shrimp farming in particular, cannot succeed in an unsuitable environment. The problem of the sustainability of shrimp industry is now the focus of many debates and discussions. The main issue being the specification and identification of what has to be taken into consideration to produce sustainable shrimp farming. In a recent article, N. M. New (1997) notes that *"it's our interest to ensure that our developments are seen to be environmentally responsible"*. Other scientists insist on the *"development and use of environmentally and socially responsible aquaculture"*. J. Clay (1997), in the same journal, addresses several environmental issues, which are (i) site selection considered as a major issue, with a strong stance against using mangrove for aquaculture (ii) elimination of the capture of wild post-larvae to avoid biodiversity decrease and disease (iii) reduction of waste though feed efficiency. J. Hargreave (1997) insists on the need to plan development with the participation of local communities and recommends the promotion of GIS, as well as an economic and social approach.

A number of scientists, government agencies, and international organisations involved in this sector strongly recommend the comprehensive approach to shrimp development, taking into account technical improvement, environmental issues, economic output and the participation of different stakeholders. Nevertheless, few investigations have been carried out on the overall shrimp farming system specifically to improve site selection and the assessment of its environmental impact and to propose methodologies for monitoring future developments.

The objective of the STD3 project was to increase scientific knowledge on site selection and on the assessment of the environmental impact of tropical shrimp farming, taking into account the protection of the environment both for the benefit of aquaculture as well as for other purposes. The study was more specifically concerned with the interrelations between the animals and their environment. One expected outcome was the development of methodologies to improve site selection and development monitoring to prevent overexploitation of sites. In this final conclusion, an analysis of the results was made with reference to the objectives defined in the early stage of the project.

First of all, a pluridisciplinary team was assembled to meet this objective, with researchers from different Institutes in Asia (Vietnam and Indonesia) and Europe specialised in shrimp nutrition, shrimp physiology, ecology, hydrobiology, remote sensing and GIS, and economists working together towards the same objectives which were:

1. to improve water and pond management by minimising effluent discharges (waste quantification and greater feed efficiency),

2. to define reliable site-selection and development-monitoring criteria that take into account the true capacity of each ecosystem to support and assimilate waste produced by shrimp farming,

3. to investigate the social and economic aspects of shrimp farming in order to reduce production costs and to improve policy and regulations for facilitating its integration in coastal zones,

4. to test remote sensing methodologies for impact assessment on a large scale,

5. to develop management tools (Geographic Information Systems) for decision-makers to provide better control of shrimp farming development,

6. to increase the scientific capability of Asian partners to study the environmental issues of shrimp farming and GIS methodologies.

Research was carried-out at the level of animal, pond and ecosystem and the programme was divided into five main parts. The results gained in each part are discussed in regard of the initial objectives.

• Results gained at the animal level

At the animal level, the STD3 demonstrated the effect of incorporating a number of ingredients into a diet to improve digestibility and thereby reduce waste production. The methodology proposed involved (i) a digestibility test specifically designed for shrimp (ii) practical and precise experiments with different diets.

This research was mainly carried out at the Centre Océanologique du Pacifique in Tahiti.

- It measured the Apparent Digestibility Coefficient (ADC) of the nutrients used in the feed pellet mixes and thus make the selection ;

- It demonstrated that the selection of higher-ADC proteins and their incorporation into the diet makes it possible to obtain higher relative growth rates ;

- It showed that the increase in RGR was achieved with a reduction in the protein content of the diet and a 20 % cut in the nitrogen released into the environment, as compared to a regular diet.

Although these results have been achieved, thus demonstrating the value of such a new approach, a lot of work still needs to be carried out to achieve a real improvement in the diet, while keeping production costs in line with economic constraints.

• Results gained at pond level

The qualification and quantification of wastes produced at pond level were evaluated under different conditions of intensity (1 to 30 post-larvae /m^2 in earth ponds; 50 to 150 pl/m^2 in concrete ponds) and under different management conditions (varying water exchange rates). This work of major importance tended to provide real values of the quantity of waste produced, along with the origin, nature and destination under different conditions of pond management.

With regard to the duration of the programme and the time for completing one experiment (1 to 7 months), it is considered that the objectives have almost been achieved for the species *P. stylirostris*.

The results can already be disseminated, with precautions regarding their use considering (i) that they have been obtained in Tahiti and New-Caledonia, where open coralline oceanic conditions prevail, and (ii) that they only concerned *P. stylirostris*.

• Results gained at ecosystem level

Characterisation of ecosystems and the follow-up of their evolution under the impact of shrimp aquaculture

This part of the programme was the major topic investigated during the STD 3 project in terms of field survey and budget. The broad investigation carried out over 3 years in different ecosystems representing different ecological conditions and aquaculture development stages encountered in tropical countries (Vietnam, Indonesia and New-Caledonia) led to three main results:

- a classification of the ecosystems studied into three categories corresponding to a degree of confinement and continental pressure from fresh water and organic matter discharge, ranging from coralline oceanic sites (New Caledonia) to mangrove and delta areas ;

- characterisation of ecosystems by the identification and selection of a limited number of relevant ecological indicators (total suspended matter, particulate organic matter, cyanobacteria, sulphate-reducing bacteria) and a comparison of shrimp farming productivity expressed in tons/ha/year. This comparison led to the compilation of a scale of observed production correlated to these indicators ;

- demonstration of dynamic of the scale: the study of economic and ecological situation of a large number of sites allowed to correlate aquaculture productivity decline with the values of ecological indicators when ecosystem deterioration was observed.

The effort made by the scientists to compare a wide range of ecosystems on a regular basis even though some were in difficult access zones, produced very useful and original data. The first attempt to improve the characterisation of these sites and monitor their evolution through the study of selected ecological indicators is certainly one of the major innovation of this programme.

Technical and economic survey of farm management and socio-economic analysis of common resources management in Indonesia

Social and economic research carried out primarily in Lampung (Indonesia) and in the Mekong delta was focused on identifying needs for collective action, including public policy, with a view to shrimp farming sustainability. The common resource considered here is coastal water quality. It was analysed by improving (1) methodology to generate information and to collect data, by comparing (2) the economic incentives (cost-benefit analysis) for farming development amongst the various technical systems and by comparing (3) the local development profiles of shrimp farming and collective action needs.

The methodology formerly developed in Indonesia (1991-1994) for data collection and analysis was transferred from one site (Java) to a new one (Sumatra) and it is conceivable to extrapolate this methodology to other provinces or countries. The quantitative aspect must accompany a qualitative analysis that is specific to each site (monographs, interviews).

A rapid survey of 1000 farms provided the basic data for the analysis of the data from a detailed survey of 100 farms. Four technical systems were identified and compared: traditional (T), traditional plus (T+), semi-intensive (S-I) and intensive (I). Classification was based on a multivariate analysis. The main conclusion is that the economic incentives for farming development are strong, but there is no significant difference between traditional, semi-intensive and intensive systems in terms of economic efficiency (profit rate above 50 %) or wealth distribution (added value between 65 % and 73 %). The relatively low results of traditional plus system can be explained by the tendency to over-stock ponds designed and managed to support relatively low-stocking density. We can say from the cost-benefit analysis that there is no evidence of economic motives to prefer one technical system over another. The difficult in verifying sustainability at low intensity levels raises questions about the soundness of public policies supporting the development of such systems against more intensive systems for precautionary reasons.

The incentives or limitations for intensification is highly dependent on other factors than profitability. Access to land, capital; know-how and markets are key factors to explain the level of intensification observed in a given area. The local ecological conditions are another important factor constraining the local potential for intensification. The production per hectare and per crop is an indicator of the local level of intensification. It shows a high differentiation among the various parts of the province and is probably partially explained by the local ecological conditions (difference between the southern part of Java sea coast and the coralline waters of Indian Ocean bays) but also by the water management structures at the collective action level (difference between the northern and southern shrimp farming areas on Java sea coast).

The main recommendation for further social and economic research is that three approaches should be investigated in greater depth. The first is the analytical approach of pond ecosystem management and its link with economic performance, as explained in the presentation of

Task 3, chapter 2. The second is to provide some expertise to help implement follow-up tools such as a database of socio-economic information that is inextricably linked to bio-technical information. The third is to investigate in greater detail the regulatory and economic means that can be used as incentives to reconcile the objectives of sustainable development and the potential for economic returns in the long term. In any event, only a pluridisciplinary approach can yield a positive contribution to the understanding of the difficulties in ensuring shrimp farming sustainability.

Remote sensing tools as helping tools for diagnosis impact of shrimp culture on the environment.

Recently, methods for processing RS data have become more convenient and people are able to handle images much more easily. Remote sensing is settling into its true position as a technique, not a science. Earth science specialists should use remote sensing as a tool to increase their knowledge of the environment, which saves them a lot of field sampling work. This means R.S. should be carried out at the very beginning of any study, and it should involve the various experts even before going into the field for the first time, following the course of action below:

- acquire the images needed for the project, according to the specific information needs, the coverage required and the funds available, together with medium-scale topographic map coverage, through local correspondents or partners. This project has shown that imagery is now currently available through the major distributors and that the problem of cloud cover may be overcome in most cases. Airborne campaigns are also practical, provided local regulations do not hamper their execution ;

- perform some preliminary processing, even with little prior knowledge of the area, overlaying the image with some other relevant data (roads, administrative boundaries, anything relevant to logistics in the field). This can even be undertaken away from the sites. Many local teams are now capable of producing preliminary work documents to assist with field work, using image and GIS processing systems ;

- gather the various experts on the project to discuss the potential contribution of the imagery to their discipline ;

- once the field campaigns have been scheduled, collect all ancillary data likely to help the interpretation in the field, and perform field work for validation ;

- perform the processing and prepare all outputs and thematic maps for use by the project experts such as hydrodynamicists, hydrobiologists, socio-economists. The output of this project has been a) detailed land-use maps in 1991 and 1995 showing activity changes in the coastal zone, particularly the surface area of paddy to pond conversions, and erosion trends, including large-scale pond maps showing the level of activity, b) the distribution of total suspended matter along the coast and its offshore extension. The latter result revealed that the water sampling locations could have been better chosen. Ideally, it should have been coupled with a simple hydrodynamic model, as the fate of the sediment loads is of major concern.

There should be a subsequent assessment with these experts of the validity of the documents produced in this manner and how they are able to integrate them into their own interpretation processes. This should lead to either confirmation or revision of their sampling scheme, both in space and time. This is the only type of framework that will produce the optimum use of remote sensing by a community of users sharing the common aim of understanding and monitoring a specific environment.

• Implementation of the training programme

The training programme has been successfully implemented considering the budget allocated. One BPPT scientist obtained a Msc in GIS application in the Netherland and three BADC researchers are completing their Msc in indonesian universities. Several short-term training courses on some specific methodologies (sulphate reducing bacteria, pond management, etc.) were proposed and taken by Asian scientists.

• Towards management tools

In a second step, the potential applications of the methodologies developed during the STD3 programme in different fields of research were discussed in terms of site selection improvement and monitoring developments to avoid overexploitation. Recommendations were made for the methodological approach to better site selection, with the identification and selection of a limited number of relevant indicators, and the choice of a specific strategy. A methodology for regular assessment of the environmental impact of shrimp farming with a view to controlling the development of sites was recommended based on the results of STD3. Data collection at farm and ecosystem level were discussed at length in terms of information requirements and processing. Although it is hard to conclude on this point, which is extremely complex in the specific context of Asia, where the existing collection system is poorly implemented, there is an obvious need to provide reliable data to facilitate the regular monitoring of development. The problem of building tools and databases that can support management decisions has recently been identified, along with the closing of knowledge gaps, as one of the regional priorities by in a FAO and NACA study of 14 Asian countries in 1997 (Naca newsletter, vol XIV, N° 2). This is particularly true in the case of the Lampung area, where shrimp farming is now developing so rapidly that the province will soon become the leading production area in Indonesia. Large intensive shrimp projects like Dipasena (5-10,000 ha) and Bratasena (15,000 ha) are being promoted in Lampung province, where they will have to coexist with more traditional developments in the future. The satellite image of these two sites presented on the cover page illustrates the size of these projects (25 km of coast line for Dipasena) and the importance of implementing methodologies and tools for monitoring the whole ecosystem under aquaculture pressure to identify any significant changes, and therefore perhaps prevent any major crises.

The proposed data collection system, presented above is bound to require adjustment, as many constraints will emerge when it is implemented. In addition, any data collection and environmental information system should be based initially on the existing national system already implemented by local institutions.

The experimental information system prototype, developed during the programme by BPPT in close collaboration with European institutes is a preliminary approach to what could be done in these sites in the future. Training was provided in GIS implementation, preliminary thematic maps were implemented, but additional work is required to incorporate more information, including ecological and economic test data and extend these methodologies to a larger scale.

• Future trend

The main result of STD3 has been to demonstrate scientifically, rather than speculatively, that an aquaculture site can only be managed by taking into account changes in the ecosystem characteristics over time and space, and the changes produced by the pressure from aquaculture and other activities. The pluridisciplinary approach made possible the development of ecological and economic methods and tools for site selection, monitoring and assessing production capacities.

At the same time, the validation of appropriate ecological indicators enabled us to monitor and evaluate water quality on a more localised basis, at the inlets to the ponds, for example.

The scientists, government agencies and decision-makers who attended the final two STD3 seminars organised in Vietnam (Nha Trang) and Indonesia (Jakarta) in June 1997 acknowledged this advance in incorporating the ecosystem into shrimp farm management. In addition to the need for continuing scientific investigation into the research areas covered during the STD3 programme, they identified an urgent need for:

(i) making the results available

There is a real need expressed by the scientific community to continue to improve site selection and environmental impact monitoring of development at national and local levels. The participants stressed the importance of transferring the methodologies already improved during the STD3 programme, and especially the hydrobiological method, to the scientists and government agencies in charge of aquaculture development. In addition, local authorities like those in Lampung suggested that information related to the evaluation of the problems and potential of aquaculture development in the areas studied should be discussed locally in order to sustain what exists, evaluate the potential of new areas and rehabilitate destroyed areas.

(ii) increasing capacity building

The need to continuously increase the expertise of Asian scientists was strongly emphasised. This can be achieved through frequent exchanges with European researchers, development of joint research work and training.

(iii) applying the methods to new models

Although relevant methodologies have been developed, participants insisted on the need to apply these scientific results to practical case studies, where crucial problems are actually encountered. This implies a move from the general application to more specific and local case studies. This is particularly the case in the Lampung area, for example, which will soon become the leading shrimp production area in Indonesia. In Vietnam, the economic development of the Mekong delta remains a priority and shrimp farming sustainability is a major concern, with more than 200,000 ha of ponds and one million people directly involved in this activity. The recommendation was to investigate a number of pilot sites in different parts of the Mekong delta, where the methodologies and knowledge gained during this programme will be applied and improved.

CHAPTER 4 - LIST OF PUBLICATIONS

Aquacop *et al.*, 1995. Determination of ADC for peneid shrimp according to a revised system. Oral pesentation WAS, San Diego, feb. 1995.

Baillet C., G. Cuzon, M. Cousin and C. Kerleguer, 1997. Effect of dietary proetin levels on growth of P. stylirostris. Aquaculture Nutrition, 3: 49-53 p.

Bailly D. et P. Raux, 1997. Etude économique de la crevetticulture dans la province de Lampung - Sumatra, STD3-ENSAR, 1997, 108 p.

Bailly D. et P. Raux, 1997. Etude économique de la crevetticulture dans le delta du Mékong, STD3-ENSAR, 1997, 52 p.

Bailly D., 1997. Crevetticulture et développement local: illustrations indonésiennes, Actes des journées halieutiques, ENSA Rennes, 1997.

Coatanea D.F., R.S. Farman and C.P. Galinie, 1997. Shrimp aquaculture in New-Caledonia: socio-economical aspects. Martinique 97, 83-84 p.

Cousin M., 1995. Etude de l'utilisation des glucides et du rapport proteines-énergie chez deux espèces de crevettes pénéides, *P. Vannamei* et *P. Stylirostris*, internal report, 210 p.

Gauquelin F., 1996. Etude de l'excretion azotée et de l'influence du régime alimentaire chez *P. Stylirostris*. Rapport de stage Ifremer/COP, 35 p.

Guelorget O., A. Lefebvre, J.L. M.Martin, A. Favry, J.P. Debenay, V.D. Son, A. Supangat, N. Tac An, P. Perthuisot, 1995. Organisation hydrologique et biologique de la région estuarienne de CanGio, delta de Mékong, Vietnam. Symposium « Aquaculture en Zone Tropicale », V.V. Lanh, N. Tac An, N.V. Chung, N.P. Phung, M. Houdart, J. Fuchs (Editors), Nha Trang, Viet nam, 18-19 décembre 1995 ; 55-85 p.

Guelorget O., J.L. M.Martin, A. Lefebvre, C. Courties, J.P. Perthuisot, A. Supangat, J. Fuchs, M. Suastica, 1996. Open sea paralic ecosystem South of Java sea, environmental approach by flow cytometry. *Journal of Coastal Research*, 12, 256-270 p.

Guelorget O., J.L. M.Martin, A. Lefebvre, 1996. Biogeological organisation and functionning of Banyuwangui bay (Java Island). *Estuarine, coastal and Shelf Sciences*. 12 p, (sous presse).

Guelorget O., J.L. M.Martin, A. Lefebvre, A. Supangat, 1997. Potential of the indonesian littoral for shrimps aquaculture. Annual Meeting of the World Aquaculture Society, Bangkok January 29 - February 2. Book of abstract, 146-147 p.

Guelorget O., A. Lefebvre, J.L. M.Martin, J.L. Bouchereau, J.P. Perthuisot, 1997. Organisation et fonctionnement d'un écosystème paralique deltaïque. La mangrove de la région de Can Gio (delta du Mékong, Vietnam). In « L'écosystème mangrove: biodiversité, fonctionnement, restauration et gestion ». Symposium, Toulouse, 10-17 juillet 1997.

Lemonnier H., J.L. M.Martin, 1996. Modelling the nature and quality of wastes in semi-intensive shrimp pond effluents. Preliminary results. Second International Conference on the Culture of Penaeid Prawns and Shrimps. Iloilo City (Philippines), 14-17 may 1996.

Martin J.L. M., 1995. Impact de l'aquaculture intensive des crevettes sur les bassins d'élevage en milieu tropical. Symposium « Aquaculture en Zone Tropicale », V.V. Lanh, N. Tac An, N.V. Chung, N.P. Phung, M. Houdart, J. Fuchs. (Editors), Nha Trang, Viet nam, 18-19 décembre 1995 ; 86-90 p.

Martin J.L. M., co-auteur, 1996. Assessment of tropical shrimp aquaculture impact on the environnement in tropical countries, using hydrobiology, ecology and remote sensing as helping tools for diagnosis. Rapport intermédiare, programme STD3, contract N° TS3-CT94-0284. 132 p. & annexe.

Martin J.L. *, J. Fuchs, 1996. Research topics of major importance for maintaining the sustainability of shrimp development. Case studies in New-Caledonia and Asia. Workshop Cantho, 1996 ; Proceeding sous press, 12 p.(* Tahiti).

Martin J.L. M., Y. Veran, D. Pham, 1996. Shrimp rearing: relationship between sewage output, stocking density and growth through the study of nitrogen budget in ponds Second International Conference on the Culture of Penaeid Prawns and Shrimps. Iloilo City (Philippines), 14-17 may 1996.

Martin J.L. M., D. Bailly, J. Fuchs, O. Guelorget, W. Malistyan, J. Populus, A. Wibowo, 1997. Assessment of tropical shrimp aquaculture impact on the environment: economic and environmental factors of sustainability. International Conference « Martinique 97 - Island Aquaculture and Tropical Aquaculture ». Les Trois Ilets, Martinique (L. Creswelle and Y. Harache, editors). European Aquaculture Society, 197-189 p.

Martin J.L. M., Y. Veran, O. Guelorget, D. Pham, 1997. Shrimp rearing: stocking density, impact on sediment, waste output ; their relationships studied through the nitrogen budget in rearing ponds. *Aquaculture*, accepté pour publication.

Martin J.L. M., P. Garen, 1997. Nature and quantification of sewage produced by shrimp aquaculture. Workshop on Coastal Environmental Management for Sustainable Aquaculture, Jakarta 7-8 juillet 1997.

Nedelec G., G. Cuzon, M. Faucon and Aquacop., 1996. Range of variation for aquafeeds at small scale in relation to growth and reproduction performances. Poster WAS, march,1996.

Populus J., W. Hastuti, J.L M.Martin, O. Guelorget, B. Sumartono and A. Wibowo, 1995. Remote sensing as a tool for diagnostic of water quality in Indonesian seas. *Ocean and Coastal Management, Vol. 27, N° 3,* 197-215 p.

Populus J., A. Wibowo, J. Prou, 1996. Use of airborne remote sensing data for the management of coastal aquaculture. *Second International Airborne Remote Sensing Conference and Exhibition*, San Francisco, 24-27 June 1996.

Raux P., 1996. Développement et aménagement de la crevetticulture sur la province de Lampung (Sumatra, Indonésie), Mémoire de DEA, Laboratoire halieutique, ENSA Rennes, 1996, 180 p.