POTENTIAL OF INDONESIAN COASTAL ECOSYSTEMS FOR SHRIMP AQUACULTURE

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Abstract

The Indonesian littoral zone shows a great variety of facies. They are represented through ecosystems going from mangrove estuaries to coralline bays. All types of ecosystems are used for aquaculture purposes, in different manners, from extensive to intensive rearing (intensification of reared surface and/or rearing density, and/or number of crops per year). The impact of the different types of activities on the ecosystem vanes according to the nature (and above all to the intensity) of the activity, and according to the nature of the ecosystem bearing the activity and, as a consequence, the sewage issued from this activity .

The goal of this study was to determine the relationship between the production of shrimps (Penaeus monodon) and the characteristics of the Indonesian surrounding environments, in order to evaluate the potentialities of the different kinds of ecosystems for shrimps aquaculture, and to determine their sensibility to the sewage. and. more precisely, to orqanic matter. Several sites representative of the Indonesian coastal ecosystems have been studied. They are located on:

1. *The Java seashore: Sri Minosari (south of Sumatra island); Cirebon and Jepara, (north coast of Java). Those sites are built in mangrove areas.*
2. *The Indian Ocean: Merak belantung, located in the south east of Sumatra Island is a coraline area.*
3. *The strait of Bali : Banyuwangi Bay, located at the east side of Java Island, is a semi enclosed bay.*

The strategy used to study these sites takes into account hydro biological and ecological characteristics, as well as seasonal variations (dry and rainy seasons). This approach allowed to define and describe the organisation and the functioning of the different ecosystems. It also allowed to analyse the place and the role of shrimps aquaculture in those ecosystems, and their potentiality for shrimp production according to the environmental (hydrobiology and ecology) characteristics of the ecosystems.

In a general way, this study approaches the problem of site selection and preservation for shrimp aquaculture, through the analyse of the relationships between aquaculture and the environment, based on concrete cases studied in Indonesia.

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I. INTRODUCTION

Several coastal sites representative of the main types all along the Indonesian coasts have been studied two or three times per year during five years. These ecological studies started in 1990 with the EURASEAN Programme AADCP and have been continued with the UE.STD 3.
The main objectives of these researches were:

1. to describe the organization and the functioning of the different types of coastal ecosystems represented in Indonesia
2. to study the same type of ecosystems with aquaculture and without aquaculture development and to evaluate the impact of the biological production on the natural environment.
3. to correlate the main environmental parameters with the production of shrimps

II. PRESENTATION OF THE STUDY SITES

The sites selected for the studies are situated on the Java Sea coast, in the communications with Indian Ocean (Bali strait and Malacca strait) and on the Indian Ocean coast (Fig.1). They represent all the caracteristic cases and situations that we can find in Indonesia considering the type of ecosystem and the aquaculture development (Supangat, 1996).

- ***Cirebon bay***, on the north coast of Java, is a historical site for shrimp culture, but also a former site for salt production. As a result, all mangrove has long disappeared. The population density here is very high, as usually in Java. Hence river inputs into the sea are heavily laden with human origin effluents. The shrimp culture started as traditional and semi-intensive and rapidly saw intensification take place in the last five years (16000 ha), (Supangat and Fitriyanto, 1998).

- ***Sriminosari,*** on the east coast of Southern Lampung province (Sumatra) has virtually no intensive ponds, but significant surfaces in semi-intensive ponds. The population there is rather limited, and so are river effluents. Mangrove has been severely affected by the shrimp activity and only pieces of the initial green belt still remain.

- The ***coast of the Jambi*** province in Central East Sumatra, is another case. Population density is very low there, making it an area for transmigration. Shrimp culture is non-existing but projects are under study or even underway. More than two thirds of the drainage of Sumatra ends up in the Java sea through a number of deltaï c formations, as is the case for Jambi province. In the dry season, let alone in the rainy one, the salinity of coastal waters remains well under average with no stratification and turbidity is dominated by suspended sediment.

- ***Banyuwangi bay***, situated at the eastern tip on the Java island, opens northward on the the Bali strait. In the strait the currents are northward during the rainy season so that the bay is under influence of Indian Ocean waters. The situation is reversed during the dry season, then the basin is influenced by Java Sea waters. The basin is elongated parallel to the general coast line and sheltered by a narrow peninsula. An important river, and several others of less importance, reach the basin

along its western side which is densely occupied by shrimp farms (5000 ha). These are fed with water by a network of channels which also evacuate the waters coming out of the ponds (Supangat and Damayanti, 1998).

- ***Merak Belantung*** (or Coco Bay) is a wide bay situated on the west coast of Sumatra. This site is characteristic of a coraline bay, with clear oceanic water conditions (Indian Ocean). Aquaculture in this site is limited to approximately 50 ha of ponds built in the sandy coastline.

III. STRATEGY OF STUDY

The strategy of study was adapted to describe the organization and the functioning of the ecosystems and to evaluate the impact of aquaculture management. The stations of studies were placed along transects established perpendicularly to the coast. So, the stations cover the whole coastal zone from the most continental part, under influence (or not) of the aquaculture farms, to the marine offshore areas.

The climate is typical of South Java Sea with two alternating marked seasons. The dry season extends from April to October, the very rainy humid one from November to march. the dominating wind is from north-east. The mean tidal amplitude is around two meters. The field survey was realized at each season to obtain the extrem conditions of the ecosystems. The main parameters studied concerned sediments and waters.

Sedimentological parameters are strong descriptors which integrate in a long term the environmental conditions and their repartition give a excellent view of the global organization of the ecosystems.

Hydrological parameters are instantaneous descriptors which have great variations in a short time and their repartition depict the dynamic of waters inside the ecosystem.

Samplings and measurements in the water were always realized in the surface and just above the bottom, in the deepest zone. In some strategic stations, the study of water considered the whole water column to precise the vertical gradient and to determine the eventual stratification of the water body.

IV. PARAMETERS OF STUDY

Hydrobiological parameters studied (Frisoni, 1984; Supangat, 1996; Guelorget *et al*., 1996) :

Physicochemical parameters: temperature,salinity,dissolved oxygen and pH
Suspended matter and organic matter
Carbon and nitrogen (C/N ratio)
Chlorophyll *a* biomasses (chlorophyll *a* and phaeophytin *a*)
Sulfate reducer bacteria
Sedimentological parameters studied (Hedges and Stern, 1984; Jaramillo *et al*., 1992; Guelorget, *et al*., 1990; Perthuisot *et al*., 1990; Guelorget and Perthuisot, 1992) : Granulometry
Carbonates

Organic matter
Carbon and nitrogen
Sulfate reducer bacteria

The main objective of this synthetic approach is not to describe with precision each studied ecosystem but to analyse the importance of several parameters as descriptors of the organization and the functioning of typical Indonesian costal zones and their relation with aquaculture.

For that reason, we selected the most important and representative parameters necessary to determine the interelations with the production of shrimps and the quality of coastal environment.

The ***salinity*** is a good indicator of the water masses repartition and by the way shows the limits of coastal zones influenced by the continental inputs. Generally, the studies have demonstrated that the salinity is very low around Java Sea all along the year, especially during the rainy season when the coastal zone is completly occupied by fresh water (Fig.2). Out of the Java sea, the coastal water is always represented by marine water even near the coastline and so the salinity has a relative stability. The important variations of salinity in the Java Sea coastal zone has a great influence on the management of the shrimp farms and on the global productivity.

The ***organic matter*** content in the waters presents globally the same organization. The quantity of suspended organic matter is very low in the open marine systems out of Java Sea but is always very high in the coastal zone of Java Sea (Fig.3). The repartition of organic matter shows positive gradients from the sea to the seashore; this gradient is more gradual during the dry season when the hydrodynamic decreases in the shallow waters near the coast in relation with the minimal pressure of continental inputs at this season.

The ***chlorophyll a*** biomasses have also the same model of repartition with positive gradients, in open systems, from the offshore to the coastal belt (Fig.3). The coastal zone water along the seashore of Java Sea has always a high concentration of phytoplanctonic populations and the eutrophication is permanent. This processus of eutrophication increases progressively because the fresh water from the rivers carries a lot of nutrients. Out of Java Sea, in the oceanic regions, the waters are always very poor in chlorophyllian biomasses with very soft gradients; the values are characteristic of oligotrophic ecosystems.

The repartition of ***sulfatereducer bacteria***, associated to the organic matter confirms the organization of coastal ecosystems studied. The high concentrations are always located along the seashore, especially in the very confined zones and in the coastal sites under influence of the waste waters coming from the ponds (Fig.4). The impact of aquaculture increases the confinement and the accumulation of organic matter in the water and, by the way, in the sediment. In consequence, the high densities are observed around Java Sea where the confinement is everywhere very strong and the cyanobacterial matts are well developed.

Here again, the repartition of sulfatereducer bacteria is organized along gradient decreasing from the continental part to the open sea.

The comparison between total suspended organic matter (TSOM), chlorophyll a biomass (Chla), phaeophytin biomass (Phaea) and salinity using a PCA (Principal Composant Analysis) model displays clear differences between the different sites (Fig.5)

The salinity is distributed along axis 3. The axis 2 represents organic matter (at left), chlorophyll a (right) and phaeophytin (far right) variations. The square's size is decreasing from Cirebon to Coco Bay according to the decrease of the variability of the parameters.

Three ecosystems are focused in the central point with a light stretching out to the salinity axis depicting an upward tendency of salinity. Their projection on Axis 2 is weak on the left (TSOM), and lightly stronger in the right depicting the sensible variations of phytoplankton with a dominance of chlorophyll a.

Cirebon Bay is widely spreaded pointing out the strong temporal and/or spatial variations of total suspended organic matter, chlorophyll a and phaeophytin a, with some stations wholly under organic matter or phaeophytin control.

Jambi estuary is out of centre towards the weakest salinities. The freshwater inputs induced an increasing of organic pressure but the importance of organic matter and phaeophytin remains largely inferior to Cirebon values.

V. RELATION BETWEEN ENVIRONMENTAL PARAMETERS AND SHRIMP PRODUCTION

The great number of data collected during five years on different typical sites allowed to correlate the main environmental characteristic and the aquaculture production. A scale was built from several multifactorial correlations using suspended matter, organic matter, chlorophyll biomass, phaeophytin percentage, sulfatereducer bacteria in water and in the sediment and the shrimp production (Tons/ha/crop). The position of each ecosystem is adjusted on the side of the scale according to the data collected in the different stations studied in the system (Fig.6).

On this scale was set the biological zonation of paralic domain from Guelorget and Perthuisot (1983; 1992). This zonation was described by observations on the benthic macrofauna in soft and hard bottoms. In some very confined ecosystems or coastal parts of an ecosystem where the macrofauna desappeared, present benthic foraminifera were used. The foraminifera are always present and well represented in all coastal biotops until freshwater ecosystems; so, the foraminifera show the limit between the paralic and the continental domain.

A part of all the ecosystems around the Java Sea are situated in cyanobacterial realm (Zone VI) in relation with the strong continental pressure inducing a high degree of confinement. These zones are completely colonized by cyanobacteria and the quality of water is not correct for the shrimps production.

The largest part of these peripheric systems of Java Sea are confined paralic zones (Zones IV-V) which are strictly dominated by primary production. The sediment of such zones still contain a great quantity of cyanobacteria and keep the

organic matter; the increasing of the organic matter accumulation induces regurlarly stratifications of the water body. The development of sulfatereducer bacteria near the bottom, under the stratification, induces dystrophic crisis, causes shrimp mortality. The shrimps production in these paralic zones is generally low in intensive aquaculture and stays between 0,5 and 3 tons/ha/crop. These zones are classically used for traditional or semi-intensive aquaculture because they have some natural trophic potentialities but cannot support excess of organic matter generally coming from pellets.

Only a small part of the ecosystems are permanently under influence of marine waters. The slightly confined zones (Zone III) are located near the communication with the sea in the semi-closed systems or all along the coastal line in the limit between continental and marine influence. Generally, in the open systems on the Java sea coasts (particularly the bays), the regions with moderated confinement are situated relatively far from the seashore and represented by a belt paralell to the coast line. These zones are certainly the most productive in term of shrimps culture. The natural evolution of the Java sea coast and the impact of aquaculture development push these zones towards the sea and it is more and more difficult to pump their waters.

In the open marine ecosystems out of Java Sea, there is no confinement and the coastal waters are only sea waters. These waters have not great natural biological potentialities (oligotrophic systems) and can receive a big quantity of organic matter without problems. These waters cannot be used in traditional or semi-intensive aquaculture but are well adapted for intensive shrimp culture. All the food comes from the pellets and the water is just a support. In this case, the production depends strictly on the quality of the pellets and the technics of ponds management.

VI. CONCLUSION

1. This first approach shows clearly that the shrimp production is in direct relation with the organization and the functiuning of the ecosystems. The confinement induces a biological zonation in term of natural biological potentialities and acceptation (or accumulation) rate of organic matter in waters and sediments.
2. This scale has to be precise with others ecosystems studies and others parameters, especially benthic bioindicators which integrate the environmental conditions in a longer term than the hydrological parameters.
3. This approach concerns only intensive shrimp aquaculture of *Penaeus monodon* but can be applied to others types of aquaculture (semi-intensive for example) and others species of shrimp as *Penaeus vanamei* or *P. styllirostris*.
4. This contribution shows the difficulty to introduce an intensive aquaculture development in a coastal area without scientific knowledge, especially concerning the organization and the functioning of the selected ecosystem.
5. Presently, a methodology to select sites in aquaculture and to evaluate its impact must be established if the long term objective is to produce and to preserve the ecosystems.

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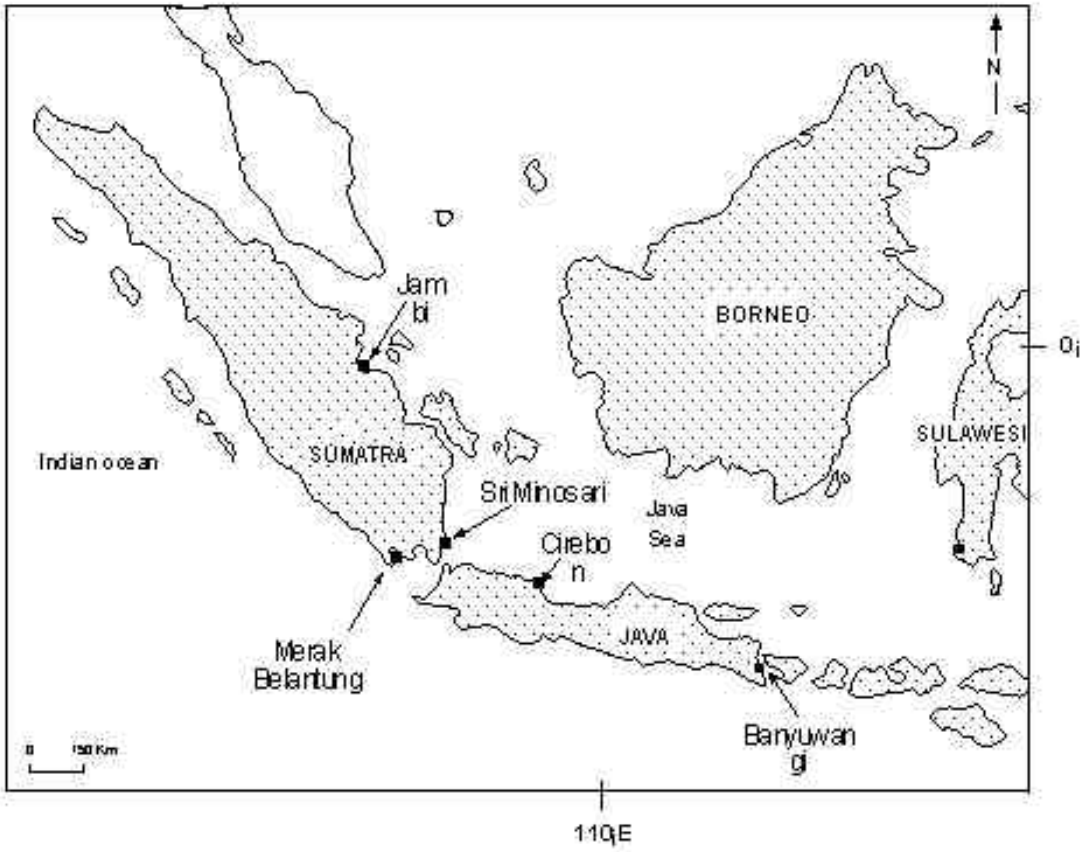


Figure 1: Location of sites studied in Indonesia

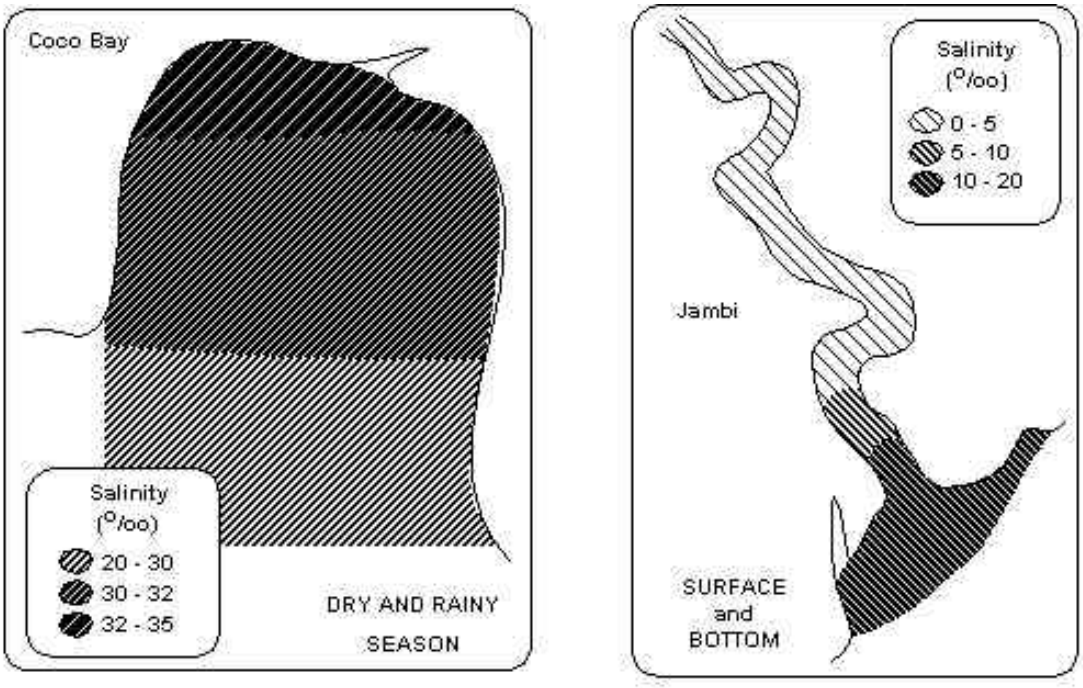
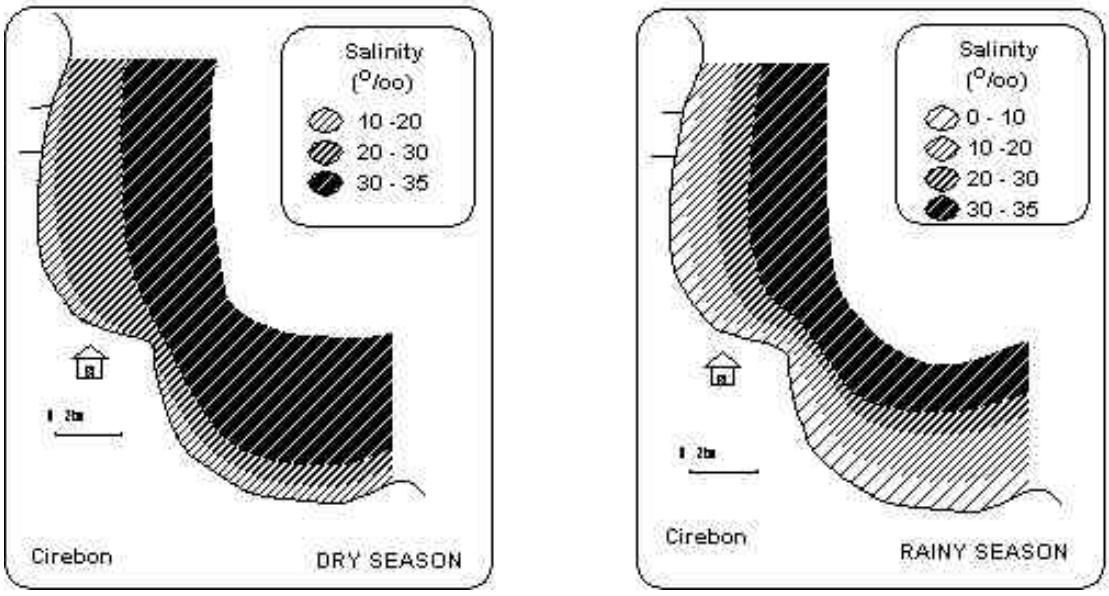


Figure 2 : Repartition of salinity in waters of studied sites in Indonesia



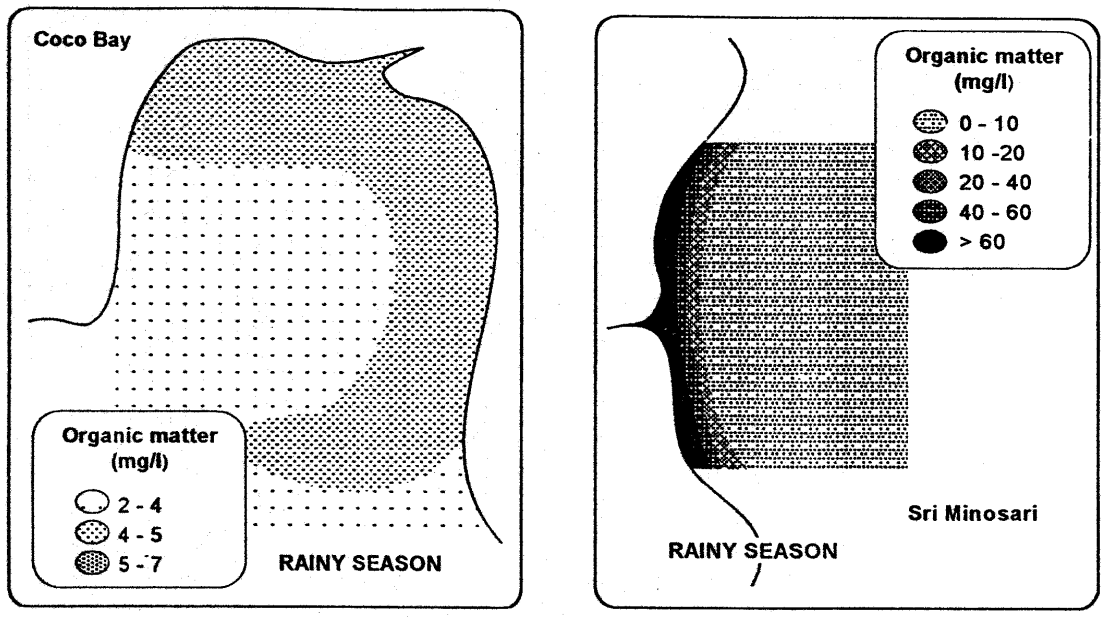
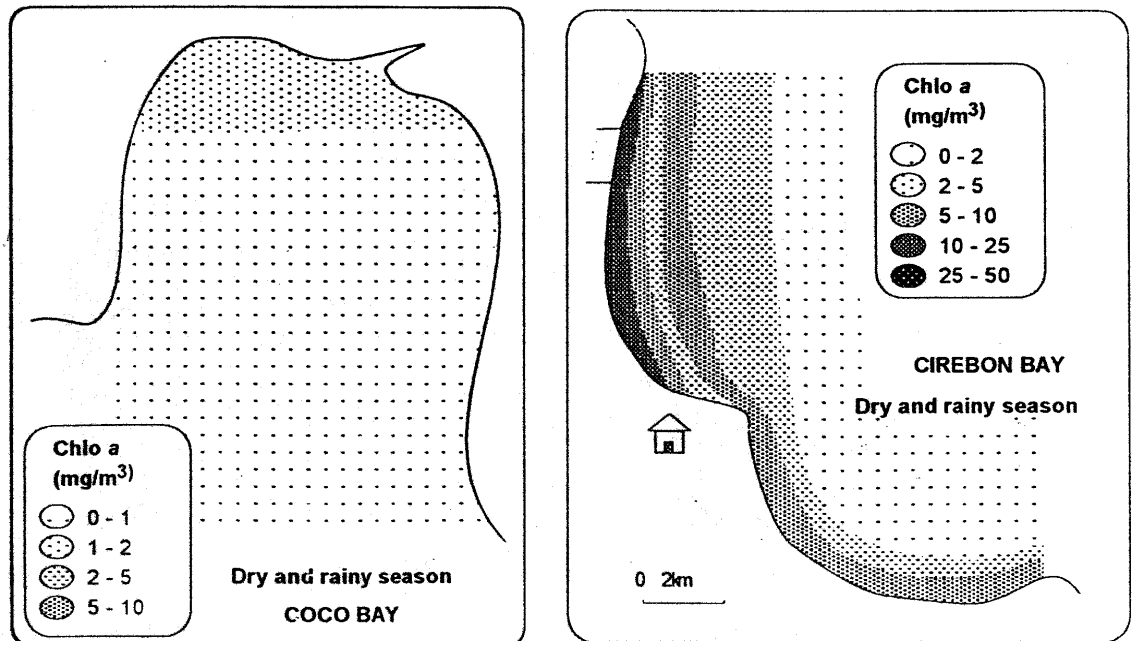


Figure 3 : Repartition of organic matter (up) and chlorophyll a biomasses (below) in waters of studied sites in Indonesia



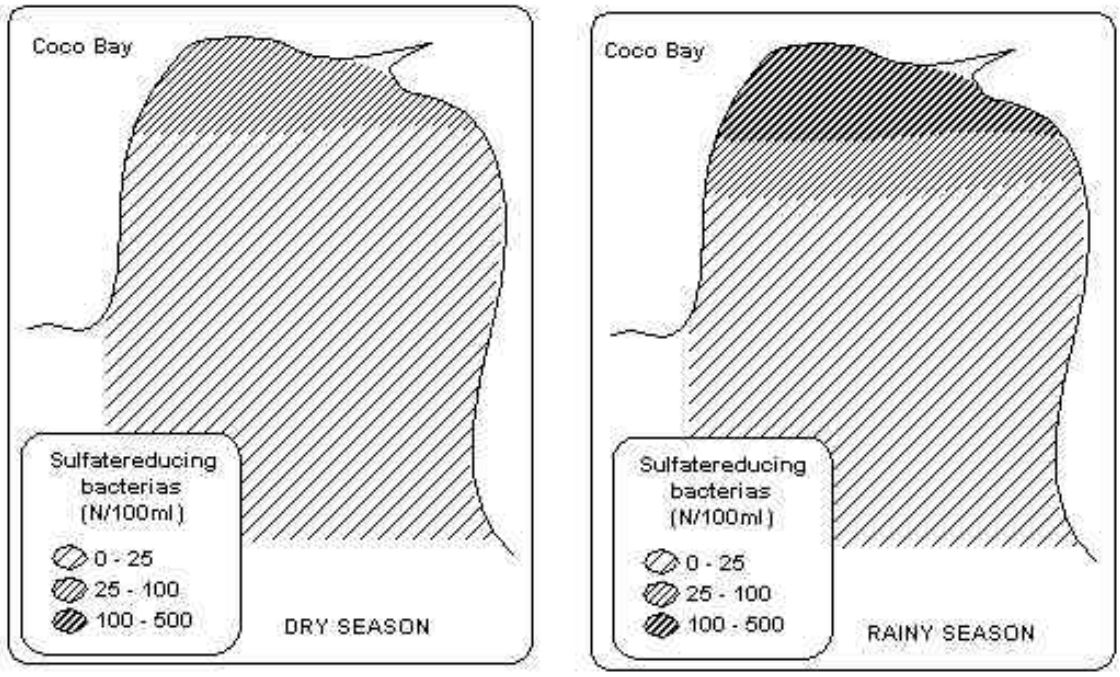
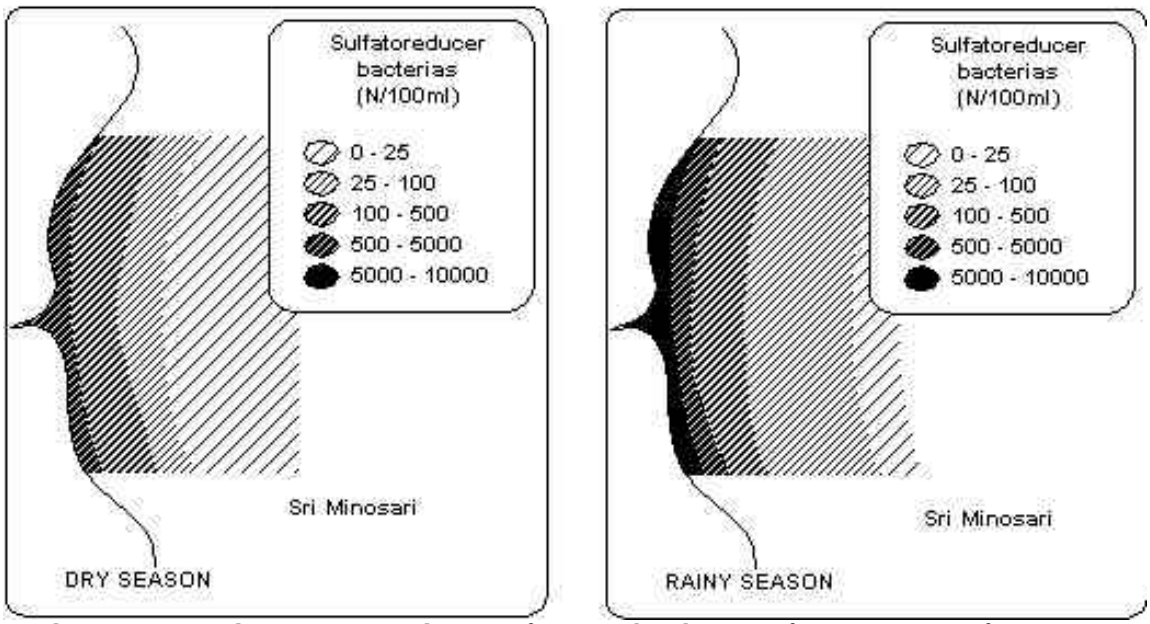


Figure 4 : Repartition of sulfatereducing bacterias in waters of studied sites in Indonesia



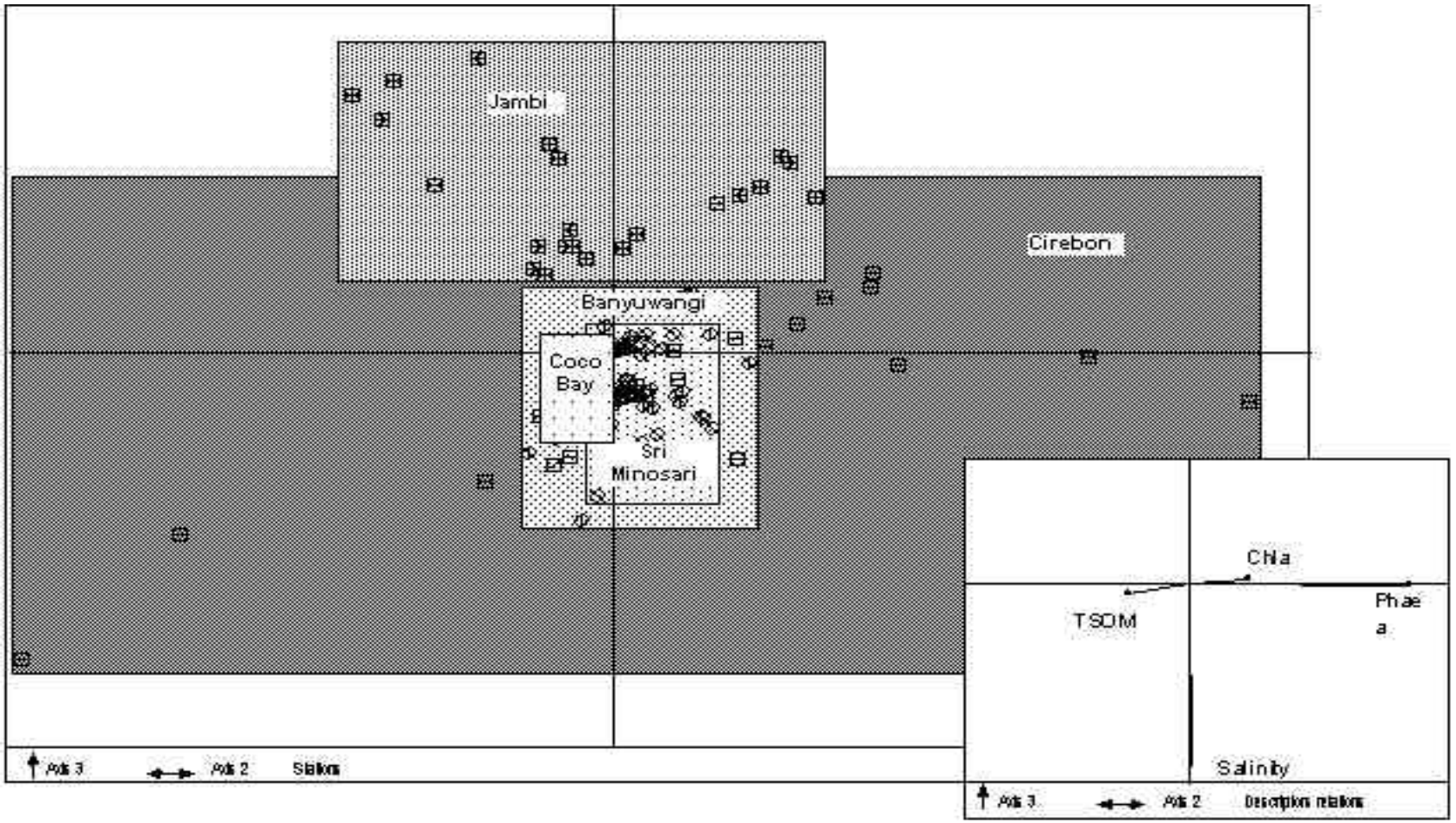


Fig 5: Representation of the different studies in Indonesia including the principal parameters as Chlorophyll a (Chla) and phaeophytine (Phae) biomasses, organic matter (TSOM) and salinity (ACP graphic)

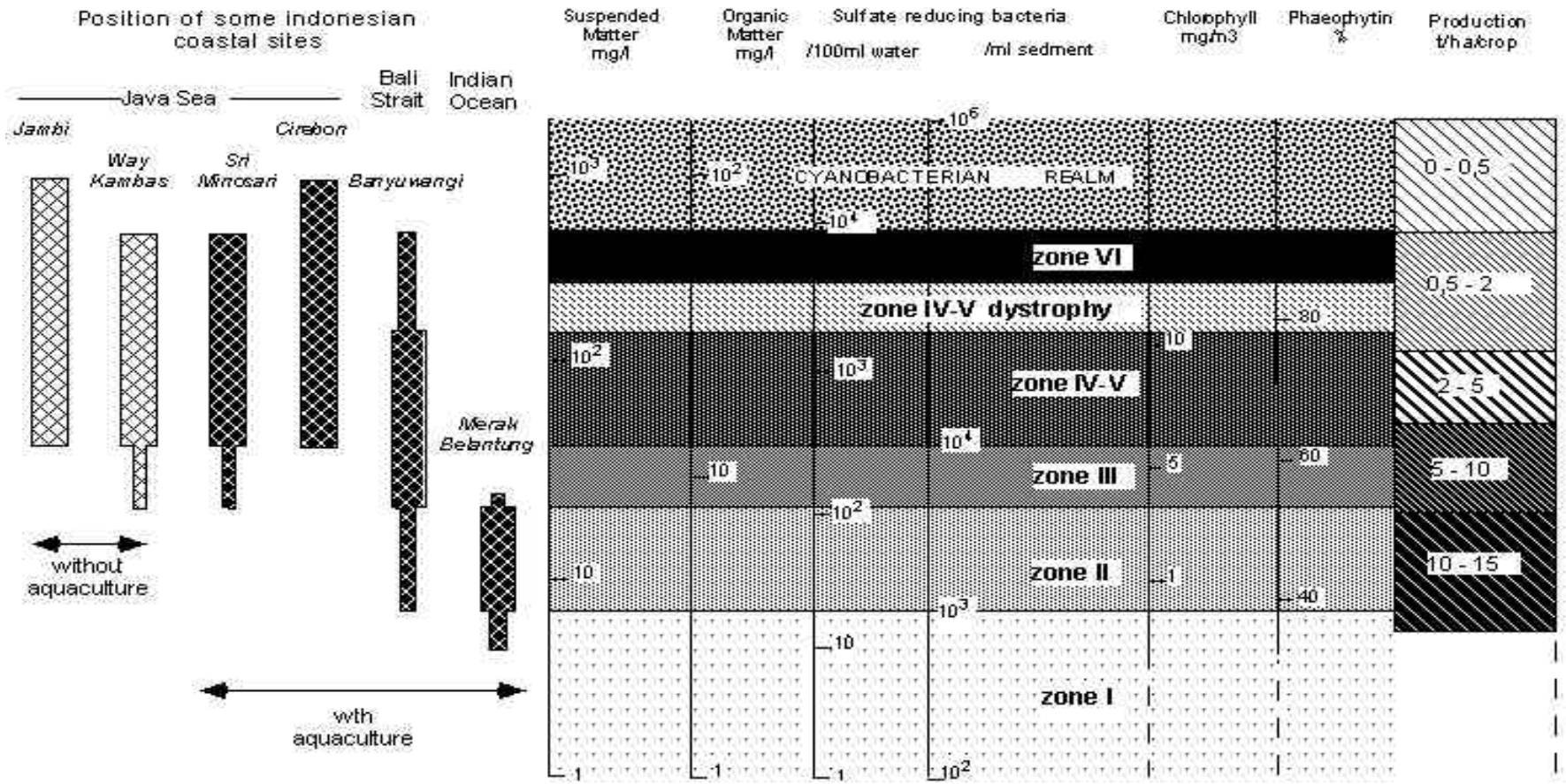


Figure 6 : Position of some indonesian coastal sites in shrimp production potentialities of paralic realm

(Supangat, 1996)