

**SIGNIFICANT COASTAL HABITATS,
WILDLIFE AND WATER RESOURCES
IN LAMPUNG**

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I. Introduction

Lampung Province has been developing very rapidly (27% growth of GDP for 1993 to 1996), and inevitably this produces a range of negative impacts to the environment which might detract from the overall benefits of development. Over the past three decades, Lampung has seen the most rapid clearance of lowland forest of any province in Sumatra. Even West and East Java, which are notorious on their loss of natural habitats, have a greater proportion of their lowlands set aside under conservation status than Lampung.

Of primary concern is the loss of lowland biodiversity as Lampung's natural habitats disappear. This is generally the irreversible result of development, as in the case of mangroves and freshwater swamp forests. Uncontrolled transmigration in recent decades has also resulted in serious degradation of the watersheds. Some 38,000 families living in the critical watersheds were scheduled for resettlement in the lowlands under the Translok program (Binnie and Partners, 1994). Within the basin of Lampung's largest river, the Tulang Bawang, forests occupied 46% of the plains and wetlands in 1969, but by 1987 only 23% remained. Only the foothills and mountains of the Bukit Barisan range in the upper river catchment do still contain closed forests. The remainder is lost or in a very critical condition, with open secondary growth at best.

The second cause for concern is the widespread impact of industries on environmental quality along the coast. More than 28,000 small and large industries are now registered with the provincial government. Decisions on land allocations for agro-industries and brackishwater shrimp farming (tambak) have resulted in sub-optimal development in a number of places, and have led to pollution, coastal erosion, loss of valuable coastal habitats (e.g. mangroves), and conflicts between sectors such as tourism and industry. Processing of crops such as tapioca and sugar cane causes severe river pollution with resultant fish mortality. Road construction, environmental management, and institutional support invariably lag behind the agricultural industry and services, making it important to invest in infrastructure facilities to sustain balanced development.

Very little, if any, of Lampung's natural habitats along the coast have escaped the impact of development, in most of cases uncontrolled, or the ignorance of proper spatial planning of resources and exploitation. A good example of this development scenario is the establishment of about 27,000 ha of brackishwater fish and shrimp ponds in an area of 17,000¹ - 56,500² ha of partly protected mangroves. However, little of the coastal habitat degradation is caused directly by poverty of traditional coastal communities. Large-scale, government-sponsored transmigration programs, uncontrolled population influx, and urban expansion have brought a rising demand for land and basic products such as water, food and fuel (including mangrove fuelwood and charcoal), and supporting infrastructure.

The high market prices fetched for shrimp grown in tambak aquaculture operations, and government policies and officials proclaiming the importance of shrimp as a national export product (e.g. Repelita V), have vigorously supported the unbridled expansion of this land-use along the coasts of Lampung, with the loss of nearly 90% of the area's mangroves as a result. The possession of tambak generally indicates a higher social status even if the fishpond appears to be non-productive, and this also contributed to the uncontrolled growth of this land use. Contrary to common reports, most coastal communities in Lampung have little regard for the importance of mangroves in sustaining their lives, and consider these forest to be of no value other than for occasional exploitation for firewood and poles. The conversion to tambak is considered doubly attractive because mangrove

¹Bina Program, Ministry of Forestry (1982)

²Based on RePPPProT (1988)

land is usually owned by the government, which means it is free for occupation in practice, and once a tambak has been established, land ownership begins to shift from the government to the private owner.

II. Mangroves

Historic and Current Distribution

Historically, Lampung had between 20,000 ha (FAO in Whitten, 1987) and 35,900 ha of mangrove swamps (RePPPProT, 1988), an interpretation based principally on landsystems and not on the actual extent of mangroves at the time of mapping. The majority were found along the east coast, particularly in the north, where fringing coastal mangroves could reach a width of several kilometres and cover thousands of hectares in an uninterrupted forest belt. In southern areas closer to Maringgai, mangrove forests were much thinner and more widely spaced, and were confined more to the river estuaries. The south coast of Lampung had a restricted area of mangroves, mainly in river estuaries and along the shores of the many coral islands in Lampung Bay. West Lampung reportedly had no significant mangrove swamps, but field surveys by CRMP need to confirm this.

From a conservation viewpoint, mangrove habitat in the province should be considered vulnerable or even endangered of extinction. Of the 17,000 ha of mangroves estimated in the 1970s (Bina Program, 1992), only about 11,000 remained in 1988-1990 based on the interpretation of SPOT and SLAR satellite data (Giesen, 1993; Vegetation Map of Sumatra-BIOTROP, 1986). However, since then large stretches of mangroves have been cleared for brackishwater shrimp farms. Formerly there were about 11,500 ha of mangrove at the mouth of the Tulang Bawang River, but since 1988 at least 6,700 ha have been cleared for shrimp production by PT Dipasena (Giesen, 1991). Estimates by the provincial forestry office indicate that fewer than 3,000 ha remain today (Ekspos Rehabilitasi Hutan Bakau Pantai Timur Lampung, 7 August 1998), although this is not based on any comprehensive field inventory or use of satellite imagery.

A field survey by the CRMP team as recently as November 1998 revealed that very little mangrove area remains, probably fewer than 1,000 ha, and most of this in a very degraded condition. The planned interpretation of a full set of TM satellite imagery by the CRMP team will provide more accurate data on how much mangroves remains, how much has been converted into tambak, and how much has been converted to other uses. Overall, this means that 94% of the mangrove areas have been lost in just 10 years, and all primarily for conversion into shrimp ponds.

A cursory interpretation of the new TM satellite imagery by CRMP gives an impression of what is left: Any significant area of mangrove forest not yet lost is restricted to the shallow coastal greenbelt along PT Dipasena's property, the Seputih estuary south of PT Bratasena's shrimp operations, some areas along the Mesuji river, and inland along the tidal stretches of the small rivers in the Way Kambas National Park. The most critical section of the coast is located between the Way Penet river down to Bakauheni in the south, where individual mangrove trees rather than mangrove forests are left. Additionally, an unknown area of mangrove remains along the shores of the approximately 60 islands off the south coast of Lampung and possibly around the Pisang and Butuah islands off the west coast.

Threats to the Mangrove Ecosystem

Conversion to brackishwater shrimp ponds is the prime – and currently the only – cause of man-

grove loss in Lampung. Before shrimp farming became popular and promoted by the government ten or fifteen years ago, mangroves were exploited for firewood and charcoal, and the latter was often exported. But never in Lampung's history has one particular habitat experienced such dramatic losses as these inter-tidal forests during the last decade. The situation is becoming worse as all natural and artificial regeneration of mangrove is halted by immediate conversion of the often-unstable mudflats to tambak. Serious shoreline erosion and loss of investments are the direct result of this mismanagement.

The mangroves growing along the shores of the coral islands in Lampung Bay have been exploited for many years by local fishermen for making poles and fishtraps, and for firewood. *Rhizophora stylosa* (bakau) is common here, and has also been exploited by fishermen for its bark, which provides tannins for treating their nets. However, locals informed the CRMP team that few of these practices are still in use, probably because most mangroves remaining at the islands are too small and stunted to repay the effort.

The biggest impact from mangrove loss is the disappearance of the natural greenbelt along the coast to protect unstable mud and sand flats from abrasion by waves and currents. Indeed, much of the coast, particularly in Kecamatan Labuan Maringgai, is experiencing serious coastal erosion which is endangering houses and village roads. The situation is very serious, particularly with regard to the function of mangrove areas in protecting the shoreline against erosion and their ecological support for near-coastal fisheries. The east coast of Lampung was known historically for its high production of penaeid shrimp, which depend on mangroves for part of their lifecycle.

Flora and Fauna of Lampung Mangroves

Mangrove vegetation along the east coast is dominated by *Avicennia alba* (api-api), with some *Bruguiera parviflora* and *Excoecaria agallocha* (buta buta). In the estuarine areas further upstream, *Nypa fruticans* (nipah), *Sonneratia caseolaris* (pedada) and *Xylocarpus granatum* (nyrih) commonly occur along the banks indicating the larger influence of freshwater (Giesen, 1991). *Rhizophora stylosa* (bakau) was found to dominate the inundated borders of the islands, including those in Lampung Bay (M. Zieren, pers obs.). This species is typical of mangroves growing on sandy soils or shallow substrates on top of reef flats.

The species composition of trees appears to be very impoverished, particularly compared to other mangrove swamps along the east coast of Sumatra. Mangroves of mainland Riau had at least 17 tree species, and those growing at the islands of Batam and Bintan had more than 40 woody species recorded (Zieren, et al., 1997). Reforestation programs by the government have used *R. mucronata*, *R. apiculata*, and possibly *Avicennia marina*.

Not much is known of the specific wildlife use of Lampung's mangroves. Data compiled from the several AMDAL reports of industrial and agricultural enterprises in the coastal zone did not reveal much trustworthy data. Among the more reliable sources are the studies done in Way Kambas N. P., an area bordering the sea in eastern Lampung that includes a restricted area of mangroves (Hapsoro, 1995; Himbio, 1995). The reserve has a total of about 300 recorded bird species, including the largest remaining population of the globally-endangered white-winged Wood duck (*Cairina scutulata*). More than 45% of the bird species are using the coastal swamps, including mangroves, riverine forest, freshwater and peat swamp forest, and the herbaceous marshes which are typical of the area.

The most characteristic fauna of the mangroves is waterbirds, including *Anhinga melanogaster* (pecuk ular) and *Leptoptilos javanicus* (Lesser adjutant/bangau tontong), a rare, protected and

endangered species. Giesen (1991) reported the occurrence of egrets (*Egretta garzetta* and *Egretta sp.*), ducks (*Anas gibberifrons* and *A. querquedula*), and waders (*Tringa totanus* and *Actitis hypoleucos*) in the estuarine swamps of the Tulang Bawang River. The beaches north and south of the Way Kambas N.P. are often visited by large numbers of waders and larger water birds, including the lesser adjutant (UNILA: Mr. Marizal, pers. comment.). Field surveys must confirm the status of these sites, which could possibly contain endangered species such as the milky stork (*Mycteria cinerea*), the migratory Asian Dowitcher (*Limnodromus semipalmatus*), and the spot-billed pelican (*Pelecanus philippensis*) (Binnie and Partners, 1994b).

Mammal and reptile species identified in the coastal zone of Way Kambas N.P. are less specific to the mangroves and could be found inland in the freshwater swamps. These include the long-tailed macaque (*Macaca fascicularis*), the estuarine crocodile (*Crocodylus porosus*) and the mangrove treesnake (*Boiga dendrophyla*).

Given the heavily degraded mangrove environment, intensive use by human, and the preliminary reports on remaining wildlife, it would be safe to conclude that none of the mangrove forests left in Lampung have significant value for biodiversity conservation, except some associated mudflats which might be important for migratory and resident waterbirds.

Function and Benefits

Healthy, well-developed mangroves serve a broad array of functions, including supporting marine fisheries, supplying building materials and other products of importance to local communities, and stabilizing coastlines. However, it is academic to elaborate on these because only a small area of mangroves now remains in Lampung.

The Way to Go

Discussing mangroves in Lampung means discussing brackish water shrimp ponds. Any plans for mangrove rehabilitation, a clear necessity, should include the control of further expansion of ponds into mangrove habitat, as well as the stabilization of pond production. This requires the close cooperation of pond owners to improve as well as sustain shrimp production. Production stabilization basically means the careful management of water quality and a sustainable production level rather than aiming at maximum production. Further details are given in Bill Marsden's report on aquaculture (CRMP).

Mangrove rehabilitation programs have been implemented by BRLKT along the coast of Labuan Maringgai in the form of community-based mangrove planting in greenbelt zone since 1994 and a so-called silvo-fishery program since 1995. About 270 ha have been replanted so far. Silvo-fisheries involve the replanting of tambak with mangrove trees, initially leaving space for the production of fish and shrimp. Later when trees become fully grown, fisheries production has to cease as a result. Both programs have failed to achieve their goals of re-establishing a protective mangrove greenbelt along the coast, and neither have gained the full support of local farmers to maintain and protect their mangroves (Zainal, et al., 1998). The reasons for this are twofold. First, on the advice of the authorities, mangroves have been planted in unsuitable locations, often along an actively-eroding shore, unstable sand and mud flats, or in the inappropriate tidal zone. Second, the programs have failed to organize the community in planting and maintenance, and did not clarify and solve the land-title problems of the rehabilitated mangrove land (including usufruct rights). Third, and most important, the programs have failed to provide sufficiently strong incentives to tambak farmers to give up the operation of affected ponds. The problem is that most tambak farmers entirely disapprove of the

idea that they should not be allowed to use (read: convert) the greenbelt zone for reasons of coastal protection.

Cultural and social reasons also play a role in the fate of mangroves. Most communities along the east coast of Sumatra are migrants from other provinces and often care less about the local environment than they might at 'home'. They are also likely to bolster their economic situation with opportunistic behavior aimed at short-term gains. The conversion of coastal swamps to wet rice field (sawah), followed by mangrove logging and the conversion into tambak fits into this 'culture of transition'. Comparing this pattern of development and land use with that of the Damar tree gardens, cultivated for more than hundred years along the west coast, provides insight into what is sustainable and what is not, even if shrimp production is the economic primadonna of the moment.

Although the silvo-fishery program for mangrove rehabilitation has failed so far, there are prospect for improvements and possible successful implementation. Rehabilitation of the mangrove greenbelt by way of silvo-fishery programs has been assessed as being economically feasible (B/C of between 4.15 and 4.19) for Lampung and offering a much higher return to farmers than the traditional approach of replanting the greenbelt in the intertidal zone (Zainal, et al., 1998). But economically feasible or not, the fact remains that farmers have to be organized, convinced, and economically capable of gradually taking some of the ponds out of production to allow for the conversion back to mangrove forest.

III. Sandy Beaches, Rocky Shores and Beach Forest

Most people associate the coastal zone with sandy beaches lined with coconut trees, rocky shores, or dry land beach vegetation; all of these are found along the coast of Lampung, particularly at the south and west. About 570 km (52 %) of the coastline consists of these habitats. The east coast of Lampung is dominated by mud flats (originating from swamps forest). See Figure 3 for the distribution of these of habitats.

Flora

A good example of how most beaches would look like left undisturbed is found in the colonization and succession of beach vegetation on the Krakatau islands. The beach vegetation established on the shores of the islands since the volcanic eruption in 1883 consists of two types: the Pes-caprae formation and the Barringtonia formation: The Pes-caprae has species typically comprising *Ipomoea pes-caprae*, *Vigna marina*, *Canavalia maritima*, *Ischaemum muticum*, *Spinifex littoreus*, *Cyperus penatus*, *Fimbristylis spathacea*, *Cassytha filiformis*, *Euphorbia atoto*, *Scaevola taccada*, and *Wedelia biflora*. The Barringtonia formation consists of *Barringtonia asiatica*, *Casuarina equisetifolia*, *Cerbera manghas*, *Hibiscus tiliaceus*, *Morinda citrifolia*, *Pandanus tectorius*, *Terminalia catappa*, and *Calophyllum inophyllum*. The Barringtonia formation is the climax vegetation for the beach and starts with pioneering casuarina and Pes-caprae plant communities (Kartawinata, 1983).

Local soil differences primarily determine the current type of beach vegetation in Lampung, but the management history also play a role. The beach forests of Lampung consist of an impoverished Barringtonia formation, with one or more of the common tree species found all along the coast of west Indonesia, including species such as *Terminalia catappa* (ketapang), *Hibiscus tiliacea* (waru laut), *Calophyllum inophyllum*, *Casuarine equisetifolia* (cemara), and *Pandanus tectorius*. *Ipomoea pes-caprae* (kangkung laut). A number of short, sturdy grasses (e.g. Pennisetum, Spinifex) grow on the sandy beach ridge of stable shores. The fauna is rather poor, but these beaches are very

important because of their use by marine turtle (see below) and the potential for tourism development.

The east coast had extensive zones of coastal mangroves, but locally both the principal coastal morphology and the soils differ greatly, resulting in sandy sediments and actively eroding and/or accreting shores, unsuitable for the expansion of mangroves. The sandy shores of the Way Kambas N. P. are dominated by *Casuarina equisetifolia*, which suggests unstable shores as well as the influence of burning -- casuarina is a typical pioneer on newly-established beaches and withstands fire well.

The west coast shows the best development of the *Barringtonia* beach formation. In combination with the white sandy sediments from reefs, this formation results in beautiful beaches with high excellent tourism potential. Also characteristic of the west coast is the dominance of *Pandanus tectorius*. The beach forests are very small, however, and bordered by lowland dipterocarp forest, village settlements and gardens, sawah or the famous Damar gardens as found at Krui.

Lowland dipterocarp forests (0 - 500 m) are outside the scope of this coastal profile, but it is important to know that very little of this forest remains as primary vegetation because of the serious impact of human settlements. Even the Bukit Barisan National Park has little of this forest, except probably in the southern part up to Tj. Belimbing - Tj. Cina.

The shores of the islands in south and west Lampung support a combination of *Barringtonia* beach forests along sandy coral beaches, lowland dipterocarp forests on steep rocky coast, and mangroves in sheltered bays.

Fauna

The most important animals using the beaches are the sea turtles along the south and west coasts and the water birds along the east coast. See the sections on freshwater swamp forests and mangroves for discussion of water birds.

There are about 250 species of terrestrial and aquatic turtles around the world. Of the eight marine species, six are found in Indonesian waters. The survival of sea turtle largely depends on the protection of their nesting beaches from the poaching of eggs and the killing of female turtles during their laborious crossing of the beach. Three species of sea turtle have been found in Lampung, with important nesting beaches known in only five locations (Tomascik, et al., 1994). The Green Turtle (*Chelonia midas*) is found on the beaches of Pulau Rakata and Sertung (Krakatau), Tanjung Cina, Krui, and the southwestern coastline of the Bukit Barisan N.P. (beaches outside the reserve boundaries). The hawksbill turtle (*Eretmochelys imbricata*) is found only on the Krakatau islands and the beaches of Pulau Segama, 25 kms off the east coast (part of the Pulau Seribu). The leatherback turtle (*Dermochelys coriacea*) is found only at its nesting beaches of Tj. Cina. All three species are rare, decreasing in numbers, and classified as endangered by the IUCN. They are also included in Appendix I of CITES, to which Indonesia is a signatory. Appendix I stipulates no trade in turtle products from natural populations. All turtles, except the green turtle, are protected by Indonesian law. Any exploitation, such as recorded for the five nesting locations in Lampung, is therefore illegal and likely to lead to extinction.

Management Concerns

The most frequent problem mentioned with regard to sandy beaches along the west coast is shore-

line erosion. Beach erosion is reportedly leading to property losses in coastal villages, damage to some coastal roads, and the loss of valuable coconut land. However, much of this erosion is neither a recent phenomenon nor the direct result of human encroachment into the active zone of the beach. Every natural beach has its dynamics in terms of periods of accretion and erosion. Building too close to the shoreline is asking for trouble.

Shoreline erosion along the east coast, particularly at Kec. Labuan Maringgai, needs further study to assess the real cause(s) of abrasion. It is unlikely that the loss of mangroves is the sole reason for erosion at all locations.

A second problem is that many beaches close to human settlements are heavily polluted with household wastes and feces. Rural settlements seldom have solid waste management systems. Fishing communities all along the coast of Lampung are known to use beaches for sanitation instead of building septic tanks, which are often too costly.

The status of sea turtles in Lampung needs further study, in particular for the west coast and the islands in the south. It is very likely that turtles use a much larger number of beaches for nesting than reported, but are unnoticed due to lack of surveys. Specific community-based management actions have to be developed for important nesting sites. The experiences of WWF in Bali can be used for this.

IV. Water and River Resources

River systems are important in coastal management because of their role in providing transport, potable water, hydrological maintenance of swamp ecosystems, and support for freshwater fisheries. Ecologically speaking, all inland areas influenced by the tidal regime are included in the coastal zone. In Lampung this includes the coastal swamps and tidal rivers up to about 60-km inland. Rivers also play an important role in the delivery of sediments to coastal systems, which feed into beaches, mudflats, and mangrove ecosystems. Rivers are unfortunately also used for discharge of wastewaters from industries in Lampung, which all end up in the coastal ecosystems with potentially negative impacts on fisheries production.

River Systems

Coastal ecosystems, including mangroves, freshwater swamps, and reefs, are heavily influenced by the type and location of river systems, which constitute the direct hydrological links between the terrestrial systems and the coastal and marine habitats.

Five large rivers and a number of smaller rivers (>25) flow through Lampung. These can be grouped into eight clearly separated watersheds (**Figure 1**). More than 80% of the land drains in an eastward direction into the Mesuji, Tulang Bawang, Seputih and Sekampung rivers systems along the east coast of Lampung. The sediments borne in by these rivers in combination with the low energy type of coast along the Java Sea has generated extensive estuaries with mangrove swamps, which formerly dominated the east coast. Rivers on the west coast typically have small estuaries due to the effect of the steep coastal profile and the strong currents and wave action of the Indian Ocean, which precludes the active expansion of the coast at most locations.

River types: The characteristics of rivers are mainly determined by the type of soils and the environmental quality of their catchments. Rivers in the south and west of Lampung were typically white

water rivers, with their catchments in the densely forested Bukit Barisan range or other mountains along the south coast. This resulted in only minimal alluvial sediments and maintained adequate river volumes year round. Large-scale land conversion and vegetation degradation has occurred in extensive areas of critical and actively eroding catchments. This has dramatically changed the water quality of the rivers discharging into the Sunda Strait in south of Lampung. As a result, several of these rivers, including the Semangka River, have changed into typical brownwater rivers with relative high turbidity levels and many organic and inorganic nutrients. Fortunately, watersheds along the west coast are in a fair condition, and the strong tradition of establishing a dense cover of tree gardens (e.g. with Damar) has maintained the environmental quality. Most rivers along the west coast were found to have crystal clear waters.

Large rivers in central and north Lampung, such as the Mesuji, Tulang Bawang and Seputih, also have the greater part of their catchment in the foothills of the Bukit Barisan mountains, but waters become mixed in their lower reaches because of the influence of coastal swamps on water quality and volumes. It is estimated that about 15% of the water volumes originates from these swamps, based on catchment size and rainfall (Giesen, 1991). Originally the coastal swamps consisted of 207,800 ha freshwater swamp forests and marshes with only restricted peat swamps. Waters draining from the swamps, such as the Pedada River (a tributary of the Tulang Bawang), were found to be acid, nutrient-poor and colored black with dissolved phenolic acids from the peat layers in its sub-catchment areas.

Additionally, much of the swamp soils along the lower river catchments in the coastal plain are of marine origin, which has led to the formation of potential acid sulfate soils (PASS), known to produce moderate to extreme soil acidity once drained and undergoing oxidation. Most, if not all of these coastal swamps are greatly affected by the extensive drainage systems and irrigation projects installed since the 1970s, as well the long history of forest exploitation for logs.

Acidity and turbidity in the Tulang Bawang River have increased, probably due to the large scale swamp reclamation schemes for transmigrants implemented since the 1980s (JITU, PITU). A large area covered these schemes has PASS in the sub-soil layers which has generated very acid soil and water conditions due to local oxidation. This has resulted in a pH of 3.1 - 5.9 in several of the primary and secondary canals in the PITU scheme. Groundwater sources for drinking water are reported to be unsuitable due to pollution with acid sulphates and saline water. These problems might increase over the years during with the subsequent drainage and oxidation of more swamps and the decrease in river debit due to irrigation and other uses in the upper section of the river (Giesen, 1991).

Table 1 summarizes some data on river catchment and debit volumes. It shows that even with a catchment area of more than 1 million ha, debit volumes of the Tulang Bawang are relatively small compared to other Sumatra rivers with catchment in the Bukit Barisan Mountains. For example, the Indragiri River in Riau, with a catchment size 1.5 times larger than that of the Tulang Bawang, has a debit range of 600 - 7,660 m³/s, or 7.5 to 21 times larger than the Tulang Bawang (Zieren, et al, 1997). The rivers in Lampung, particularly those flowing eastward, show strongly seasonal variation in water volumes and levels. This is a direct reflection of the rainfall pattern in central and west Lampung, where there is little rain from June to October and heavy precipitation from December to March (RePPProT, 1988). The Way Seputih, for instance, has a relatively modest average debit, but water flows in its tributary, the Way Pengubuan Terbanggi Besar, fluctuate between 2 m³/s to 118 m³/s (PU, 1996). The extreme water fluctuations, and in particular the low flows, impose restrictions on the potential use of the rivers, wheter agricultural, household, transportation, or industrial. One of the clearest examples is the severe pollution of the small tributaries of the Seputih River.

Because of their low water flow, these streams cannot handle the wastewaters generated by the local agro-industries, although these are generally kept below the effluent standards set. Relocation of industries should be considered as an option.

Fluctuating river levels are further exacerbated by the tidal influence that extends at least 60 km inland along the Tulang Bawang River (e.g. at the Pedada tributary). During heavy rains, riverbanks overflow and adjoining freshwater swamps are inundated. This creates productive wetlands full of fish and water birds. Water levels such as at Nibung and Bawang Lampu Purus in the Way Kanan floodplains can rise by up to 3 meters. Peak flooding is normally in January at the height of the west monsoon, when the floodplain storage is filled. These swamps function as buffer for the freshwater supply downstream used by the transmigrant farmers of the coastal scheme at JITU, who can not use the polluted local groundwater. Flooding of land is a routine and natural phenomenon of river systems like the Mesuji, Tulang Bawang, Seputih and Jepara rivers.

The feasibility studies for the reclamation schemes along the Tulang Bawang and Mesuji rivers recommended maintaining deep-water flooding zones around Manggala town and the swamps of Lambu Purus, Tenuk and Bakung for flood storage, fisheries and nature conservation (Binie and Partners, 1994b).

Table 1. Catchment size and debit volumes of major rivers in Lampung

River catchment	Catchment (ha)	River type	Debit range (m ³ /s)
Mesuji	Largely in Sumsel	brown (mixed black)	155
Tulang Bawang	1,015,000	brown (mixed black)	80 - 360 (av.200)
Seputih	755,000	brown (mixed black)	3 - 48 (av. 26)
Way Jepara	88,000	mainly blackwater	36
Way Kambas	44,000	mainly blackwater	10
Sekampung	567,500	brown (mixed black)	216
Ullubelu/Napal/Siring	several	brownwater	-
Semangka	152,500	brownwater	0.18 - 247 (av. 67.5)
Krui	66,000	whitewater	40
Pamerihan	33,000	whitewater	13

Source: Giesen, 1991; Manik, 1991; BPS, 1997, REPPProT, 1988; PU, 1996

Given the volumes of freshwater, sediments and pollutants carried by the Mesuji, Tulang Bawang Seputih, Sekampung rivers along the east coast, and the Semangga River into Teluk Semangka in the southwest, these rivers are the most significant in Lampung with regard to the maintenance of coastal ecosystems and their productivity.

Riverine habitats: Three different types of river habitats are found in Lampung: the white water type with quick-flowing and clear waters and modest concentrations of dissolved nutrients; the black water rivers colored by dissolved phenolic tannins, poor in nutrients and high in acid (pH 3.2-4.8); and the brown water type with some mixture of blackwater from the combination of drainage of coastal swamps and large catchments in the foothills and mountains inland. The brown water type is rich in nutrients and sediments, and slightly acid to neutral (pH 5.6 - 7). As a result, biological

productivity, as expressed in the diversity and quantity of fish and plant communities, is significant different in these three river types.

The Pedada, a tributary of the Tulang Bawang, is an example of a **black water** river which drains the originally freshwater and peat swamps along the coast of north Lampung. Others, such as the Way Rasau (Seputih river) or the Way Wako, both in the Way Kambas N. P., have r typical slow-flowing (average 15m³/s) and coffee black waters similar to the Pedada river. The aquatic vegetation of these rivers is characterized by floating mats of the exotic *Salvinia molesta*, and species such as *Ceratopteris thalictroides*, *Cyperus*, *Eriocaulon longifolium*, *Ludwigia hyssopifolia*, *Lycopodium cernuum* and *Hanguana malayana* (a peat indicator). The black water rivers have a low level of fish production because of the lack of primary nutrients, low dissolved oxygen and restricted primary plant production. This does not, however, exclude these rivers from producing economically-important fish such as the *Anabas testudineus* (Betok) and *Scleropages formosus* (Arowana), among the minimum of 14 species recorded for the Pedada (Giesen, 1991). The arowana is a popular ornamental fish, and large specimen (40 cm) of the reddish variety found in the Pedada may sell for as much as US\$ 800 each.

On the other hand, a **mixed brown water** river such as the Tulang Bawang has a faster flow (average 200 m³/s) and a poorer vegetation diversity of aquatic macrophytes. These include mainly *Eichhornia crassipes* (eceng gondok), floating mats of *Hanguana malayana* along the riverbanks, and a number of sedges, including *Cyperus* spp. and *Eleogaris* spp. However fish diversity and production is much greater due to the river's high water quality, higher level of nutrients available, and productive swamps along its floodplain. Preliminary inventories of this river showed a minimum of 39 fish species, including *Kryptopterus* (3 species: Lais/Selais), *Notopterus chitala* and *N. borneensis* (belida), *Mystus nemurus* (baung), *Oxyeleotris marmorata* (malas), *Tetraodon* spp. (buntal) and *Wallago* spp. (tapah/ketibang) (Giesen, 1991, Rusila Noor, et al., 1994). Overall, the Tulang Bawang swamps and tributaries contained 88 fish species from 24 families (Rusila Noor, et al., 1994). More sampling upstream and in the catchment in the hills and mountains could very likely increase the number of species, especially those typical of small, quickly-running mountain streams.

River and Swamp Fisheries

Freshwater fish supply vital animal protein to a growing population, both inland and along the coast, and provides employment to rural people. There is not much data available for river and swamp fisheries along the coast of Lampung, except for the Tulang Bawang system. A description of this area is considered representative for the remainder of the freshwater fisheries of the Mesuji, Seputih, Jepara and Sekampung river systems.

Swamp and river fisheries provide a major source of income for the inhabitants of villages along the Tulang Bawang River. The fisheries follow the seasonal cycle of spawning and breeding in both rivers and swamps of Tulang Bawang during the early wet season, followed by a fairly rapid growth during the mid to late wet season. During the wet season, most fish are caught by fishing and trapping in the inundated swamps and drains in the transmigration schemes. During the dry season, fishing involves harvesting fish from the many small ponds and depressions as they gradually dry up.

Fishery techniques are simple and traditional. Four main methods are used: (i) fish nets and fixed traps in creeks and man-made drains connecting the river with the back-swamps; (ii) hook and line; (iii) gill netting along river banks; and (iv) capture in receding waters of ponds and ditches. The low level of technology of the fishing gear has played an important role in the conservation of fish stocks until recent times (Binnie & Partners, 1994a). Normally fishermen can obtain an income of at least

Rp 300,000 per month during the wet season, and up to 2 to 3 times this amount in the dry season, which is the peak fishing period. Problems occur late in the dry season with pollution from cassava and sugar factories (Rusila Noor, et al., 1994).

Most of the riverine and swamp fisheries appear to be freely available to all fishermen, except a few areas where fishery rights are restricted, as below:

- specific, identified locations where fishermen have historically laid nets or traps;
- use of man-made canals and ditches (lebung/lubuk) to trap fish as described previously; and
- annual auction of fisheries.

The auction of fisheries (Tempat Pelelangan Ikan - Fish Landing Place) occurs in about 48 locations in the Tulang Bawang swamp/river system, particularly within Kecamatan Tulang Bawang Tengah. Traditional fishing rights including auctioning, results in a high proportion of the fish catches being channeled through a fairly limited number of more influential traders. Through the auction system, fisheries revenues are passed on to the villages and local government.

Dinas Perikanan reports a fisheries production for 1996 of:

	Kab. Tulang Bawang	Kab. Lampung Tengah
Sea Fisheries	5,541 tonnes	42,577 tonnes
River and Swamp Fisheries	4,169 tonnes	4,155 tonnes

BPS, 1997

River and swamp fisheries production in Kab. Tulang Bawang comes from the Tulang Bawang system and a proportion of the Mesuji river system. Inland fisheries have higher production rates than sea fisheries, which probably indicates the lack of sufficient infrastructure for sea fisheries. The consultant team doing an aquaculture study for the feasibility review for the Southern Sumatra Water Resources Project calculated fish production of about 20-100 kg/ha/yr for areas depending on swamp/river, inundation regimes, vegetation, and natural fertility. Initial estimates give an annual production of around 5,000 tonnes from the swamps and 969 tonnes from the river in the Tulang Bawang system (Binnie and Partners, 1994a). This correlates closely with the data of Dinas Perikanan, and shows the importance of the coastal and inland swamps (85% of production) for the local fishermen. The picture is complicated by the estuarine area, with its combination of marine and freshwater species.

Trends in fish production from rivers and swamps: The general trend shows a decline in fish production, based on information from individual fishermen, Dinas Perikanan, and the prices received at fish auctions. For example, fishing rights in the Bawang Lambu swamps used to yield 100 tonnes about 20 years ago but is now only yielding about 30-40 ton (Binnie and Partners, 1994a). The reasons for the decline may include the following:

- Gradual silting up and increased vegetation growth in the swamps and smaller rivers. Exotics such as *Eichornia crassipes* and *Salvina molesta* choke the waters with dense floating mats, decreasing oxygen levels and inhibiting fish life.
- Loss of swamp areas, and thus fisheries, as a result of the Rawa JITU and PITU schemes.
- Increased levels of water pollution from agro-industries, which cause annual mass fish kills (at least since the mid-1980s).

- Very heavy fishing pressures beyond the maximum sustainable yields. Giesen (1991) reported that belida, malas and arowana have become very rare in the Tulang Bawang River system. Frequent reports of electric fishing and use of fish poisons (which is illegal) indicate possible heavy damage to fisheries.
- Increased level of suspended solids (TSS) from soil erosion in river catchments. This plays a role in reducing fish production.

Proposals have been made for development of the fisheries of the Tulang Bawang river system as part of the integrated development of rice and fisheries along the Tulang Bawang Flood Plain (Binnie and Partners, 1994a). The proposed components include:

- Establishment of fish conservation areas (swamps);
- Development of areas for managed fisheries, e.g. the swamps and sections of the river;
- Development of areas for integrated rice and fish production (mini paddy);
- Development of brackishwater aquaculture areas (prawn, cockle, and green mussel), to the south of the Tulang Bawang and the north of the Mesuji rivers (South Sumatra).

The (temporary) halting of any expansion or upgrading of the existing swamp reclamation schemes (JITU, PITU) has still prevented a follow up to these initiatives for fisheries development in the rivers and swamps along the coast.

Water Quality and Condition of River Catchments

Degradation of river catchments: Several of the river catchments are reported to be in a critical condition, resulting in high rates of soil erosion due to the degradation of vegetation and lack of soil conservation measures in areas converted to agriculture. Much of the steeper land has been included as protected forests but few areas have escaped logging and conversion to agriculture. More than 60% of the protected forests are reported to have been lost, although an estimated 70,000 ha have been converted into coffee plantations (Staff Sub-Balai RLKT, pers. comm.). By 1996, a total of 811,685 ha of protected forests and areas in conservation reserves had been lost in Lampung (particularly in Bukit Barisan N.P.), which indicates the low level of protection of forest resources in the province.

Since the 1970s, reforestation programs have been implemented to improve the condition of watersheds, but an estimated 634,270 ha remains as critical land. The data show that only Kab. Lampung Barat has limited critical land, with 88.5 % in the remainder of the province (BLH, 1996). The area of critical land would significantly increase if the areas of heavily degraded and presently unproductive coastal swamp 'forests' were also included in the statistics. Most of these swamps have been logged, drained, or otherwise converted and remain classified as 'belukar' or forest, although their present vegetation is an open stand of gelam (*Melaleuca cajuputi*). While the gelam forests and associated herbaceous swamps have significance for fish production and biodiversity conservation, they are rather unproductive and in a critical condition from a forestry viewpoint.

Soil erosion and sedimentation rates have been established for the Tulang Bawang and Seputih rivers. Erosion rates in the Way Kanan sub-catchment of the Tulang Bawang system average 310 ton/ha/yr. at an average. The Way Kiri averages more than 850 ton/ha/yr. This results in an annual sediment load of more than 4 million tons (or about 2 million m³) for the Way Kanan sub-catchment

and about 6.8 million tons (or about 3.4 million m³) for the Way Kiri sub-catchment (Utomo et al, 1991). Measurements of total suspended solids (TSS) show a range of about 250 to 650 mg/l for the upper watershed up to Manggala. How much additional sediment is contributed by the middle and lower watersheds and how much is eventually deposited eventually in the estuary or along the coast of the Tulang Bawang system was not analyzed. The fact is that many rivers are reportedly extremely shallow at their mouths, which often precludes river transport during low tides. Although the Tulang Bawang is the largest river in Lampung, its total sediment volumes are at least 3 to 4 times lower than comparable rivers such as the Kampar and Indragiri in Riau, which each deposit about 17 million m³ each into the coastal system each year.

The watershed of the Seputih River has an average soil erosion rate of 215 ton/ha/yr (range: 5 to 415 ton/ha/yr), which is far above allowable erosion level of 35 ton/ha/yr for similar types of land resources. This means that a maximum of 10.5 million ton sediment (or about 5 million m³) is flowing annually into the Seputih river system (Manik, 1991). No comparable data are available for the other rivers on the west and south coasts. It is clear, however, even with restricted data, that the rivers flowing into the Java Sea on the east coast are the main contributors of sediments (both natural and man-made) into the coastal system, which accounted for the formerly large expanse of mangroves along this side of the coast compared to the south and west of the province.

Probably only one of the southward running rivers, the Semangka, needs to be considered with regard to its sediment load. The catchment of this river contains a large proportion of critical land, and given the high rainfall and steep terrain, is expected to carry considerable amounts of sediments. This was confirmed with the observation of sediment-loaded seawater in the northwest of Semangka Bay both on the TM satellite imagery and by the CRMP field team surveying the coral reefs along this coast (Naviati, pers. comm.). It was found that the average TSS levels for Lampung Bay ranged between 11 and 13.5 mg/l, which is slightly higher than the recommended allowable level for near coastal waters, set at 10 mg/l (BAPPEDA, 1997; Watson, et al., 1993). Sedimentation and reef condition will be assessed by this survey team.

Chemical pollution of river water: Like most of the other provinces in Indonesia, Lampung experienced impressive economic growth until the present economic crisis in Asia. Overall, Lampung achieved 27% growth of GDP between 1993 and 1996 (BPS, 1997), with much of this growth related to new agro-industries. More than 22,000 agriculture and forestry industries are registered with the government, of which 505 medium to large industries. Additionally, more than 5,850 medium to large size chemical, metallurgic and machine factories are registered, mostly along the coast in the south or in central Lampung.

Some of the biggest agro-industry based producers are summarized in **Table 2**. Many of the medium and large industries are situated along the rivers for access to transport and an ample supply of fresh water for the production processes, but most probably as a discharge for their waste waters. The production of tapioca, pulp, citric acid, sugar molasses, and crumb rubber has caused severe river pollution and caused repeated mass fish kills (Giesen, 1991, Binnie and Partners, 1994). Serious fish kills in the Way Miring and Way Pedada rivers are well-documented and directly linked to pollution from the processing factories.

Table 2. Selected important agro-industries and production levels

Type of Product	Total production 1996 (ton)	Note
Coal	250,727	Export volume
Crumb rubber	55,120	
Soaps	25,201	
CPO	73,993	
Pineapple	39,651	Export volume
Molasses	58,614	Export volume
Tapioca crisps	133,156	Export volume
Tapioca starch	11,053	Export volume
Shrimp	12,439	Export volume
Bananas	44,231	Export volume
Coffee	203,654	Export volume
Mono Sodium Glutamate	12,063	Export volume
Plywood	24,070	Export volume
Citric acid	8,057	Export volume

Source: BPS, 1997

No exact data could be obtained on the numbers of industrial plants, but it appears from the ongoing Kali Bersih Program (Prokasih) program for Tulang Bawang, Seputih and Sekampung that the largest number involve tapioca-based industries, followed by sugar cane, crumb rubber, and citric acid.

Prokasih has been implemented in the province since 1988, but is restricted to monitoring the effluent of a selected number of agro-industries along the Tulang Bawang, Seputih and Sekampung river systems. Presently wastewater from 74 factories is being monitored as it is discharged into the rivers. Firm action against polluting industries, mainly having simple treatment plant installed, could reportedly have reduced organic pollution by 93% between 1989 and 1995. However, treatment remained insufficient at 26% of the factories and their effluent continued to pollute the rivers (Biro LH, 1995). Due to the large volumes of water used by agro-industries, large volumes of wastewater are generated. For example, between 36 million to 56 million cubic meters of wastewater were generated for the production of about 700,000 tons of tapioca in Lampung in 1994 (BAPPEDA, 1991b; Karden, 1995). Production volumes are now much higher. Typical effluent BOD values are: tapioca 102-215 mg/l; crumb rubber 110 mg/l; citric acid 102-178 mg/l; cane sugar 138 mg/l; pulp 123-196 mg/l. The biggest polluters based on COD of effluents are: tapioca 210-450 mg/l; citric acid 220-389 mg/l; pulp 305-388; and rubber 235-245 mg/l (data program Prokasih, 1995-1998).

The tapioca and sugar factories operate primarily when river flows are low, and the effluent is generally discharged into small tributaries that do not have the capacity to absorb it. While pollution levels in the main Tulang Bawang River are not yet critical, there are serious problems in Way Miring (a tributary of the Way Bakung), Way Pedada, and Way Bujuk, which is the source of water for the Way Pedada Scheme (Binnie and Partners, 1994a). The Lampung government has therefore developed local effluent standards which are specific to the industries in Lampung and indicate the need to have standards 25% - 60% below national levels to better reflect the lower pollution capacity of the river tributaries (SK Gubernur No. G/624/B.VII/HK/1995; Baku Mutu Limbah Cair

Propinsi Daerah Tingkat I Lampung).

Ironically, government studies on the pollution load do not include any evaluation of wastes generated by brackish water shrimp farming, which was assessed to contribute 90% of the organic materials being put into the Tulang Bawang River (Binnie and Partners, 1994a). During low flow periods, the effluents of PT Dipasena can reduce dissolved oxygen levels by up to 8 mg/l (although tidal movement may have strong mitigating effects). Given the average DO levels of about 4-6 mg/l in the river, this would mean an unacceptable pollution load and subsequent impact to fish. Fish would normally not survive in waters with a DO of 1 mg/l or less. It is important to do a study on the pollution loads generated by the more than 25,000 ha of tambak in Lampung, of which more than 80% are found along the east coast.

A further point of concern is that effluent monitoring by Prokasih does not include any assessment of the potential toxicity of wastes to aquatic life of wastes such as Cn (arsenic) from tapioca production. The annual mass fish kills could be related to this pollutant rather than the input of organic wastes. Other effluent components that should be monitored are the liquid phosphates, Ca(OH)_2 , NaOH, and SO_2 , being used in cane sugar production, by the Gunung Madu Plantations factory along Way Pengubuan and by PT Gula Putih Mataram along Way Terusan.

Other non-point pollutants of water resources: Unfortunately, little information is available on water pollution from substances such as heavy metals from metallurgic/chemical factories, pesticides (e.g. Thiordan) used in brackishwater shrimp farming, or the fertilizers and pesticides applied in agriculture. Additional sources of pollutants include sewage and household wastes. Characteristic of most of these pollutants is that they occur at a regional scale, with diffuse points of discharge, and often remain unnoticed by the common observer.

The rapid growth of the agricultural sector in Lampung has increased the use of chemicals. A short inventory of fertilizer use in 1991 shows that about 15 different types of fertilizers were used, with most farmers (81%) applying urea and TSP (super-phosphate) (UNILA, 1991). Quantities are not known, but from the provincial import data we learn that 169,060 tons of fertilizers were purchased for Lampung in 1996 (Lampung Dalam Angka, 1996). Assuming that this quantity was consumed in 12 months, this means that an average of about 150 kg/ha were used annually on Lampung's 1,126,870 ha of agricultural land. The most dominant crops are maize, peanuts, soya beans, sweet potatoes, green peas, paddy, and cassava; with the largest area of land occupied for cassava and rice. The recommended fertilizer input for rice paddy amounts an average of 195 kg/ha for Urea and 130 kg/ha of TSP per crop; for cassava, it is 130 kg/ha of Urea and 106 kg/ha of TSP (UNILA, 1991). Based on the data, and assuming two crops a year for sawah rice and cassava, it appears that fertilizer use is reasonably in line with the recommended doses, especially if we consider that most of the cassava and rice paddy have two crops a year. Other sources mention however an average fertilizer use is reasonably in line with recommended doses. Other sources mention an average fertilizer use of 329 kg/ha (range 0 - 430 kg/ha, with highest inputs for rice, maize, soya bean, and chilis), which is much higher than the recommended levels (BLH, 1996). This reportedly required a total amount of 415,151 ton of fertilizer for Lampung in 1996. It is unclear how much of this fertilizer is used effectively by the crops, how much is lost due to weather and bacterial activities, and how much ends up in ground and surface water.

It is clear that there has been a steady increase in the nutrient load (nitrogen, phosphate, sediments, etc.) carried by the river systems due to increased fertilizer use, increased soil erosion in the watersheds, and input from other sources, such as sewage from an increasing human population (from about 2.7 million in 1971 to more than 6.8 million in 1998). An indicator of the gradual eutrophica-

tion of the rivers is that many of the smaller tributaries with small debits have become choked with weedy aquatic species such as *Eichornia crassipes* (eceng gondok) and *Salvinia molesta* (kiambang) (Giesen, 1991). Both exotics have become pests in several lakes and rivers in Indonesia in waters with increase organic nutrient levels, including Rawa Pening and Lake Kerinci (Soerjani, 1976; Giesen and Soekotjo, 1991). The species are known to block waterways, deplete water oxygen levels, increase evaporation, and choke hydropower plants.

It is also important to assess the scale of pollution of coastal waters from sewage and household wastes. Sewage consists of human feces and household wastewaters. Data on sewage systems in Lampung are incomplete and cannot be used for evaluation because they only cover about 1/6 of the provincial population (BLH, 1996). However, an estimation can be made for BOD from sewage discharge (**Table 3**). This estimation shows that the daily amount of household sewage represents a BOD of 172,2 tonnes for the entire coastal population in Lampung (compared to the 21 tonne BOD load reported from the agro-industries monitored by the Prokasih program since 1989). This assumes that 60% of the households are connected to a primary sewage treatment system, which is much higher than the actual situation in Bandar Lampung. This means that actual discharge and BOD volumes are considerably higher.

Many of the beaches in Lampung are reportedly polluted with human feces because coastal communities have not built proper sanitation facilities and use the beach instead. Sadly, many of these beaches would have a high potential for tourism development or other recreation if they weren't polluted. The seriousness of the present situation along the coast of Lampung is illustrated by Pulau Pasaran in Teluk Betung, with its traditional processing of salted fish (Ismono, et al, 1996). It was found that 77% of the families did not have access to a toilet (they used the beach instead), 93% of the families dumped their household waste directly into the sea, and 90% of the families disposed their wastes from fish processing into the sea without any collection or treatment.

Table 3. Estimated daily BOD loading from sewage discharge in coastal areas of Lampung for 1998

Parameter	Value
Provincial population (million)	6.8
Total BOD (ton)	340
Coastal population (million)	4.2
% provincial population	65
Daily BOD load in coastal area	
Generated (ton)	210
Primary treatment (%)	60
Secondary treatment (%)	0
Daily BOD removal (ton)	37,8
Residual daily BOD disposal (ton)	172,2

Source: adopted from Koe and Aziz, 1995, in Chua et al, 1997

Solid wastes are an additional source of pollution in coastal areas, as well being a nuisance to the eye and nose. Only a small percentage of the total household wastes generated, estimated at 2,724 tons annually, are managed properly in Lampung (BLH, 1996). As with sewage, a large fraction of this is generated and deposited in the coastal zone and along waterways. Only about 14% of total household waste generated is collected by private firms installed by the government or at local initiative. The remainder is burnt or disposed of in an uncontrolled way. Rain and wind distribute part of the wastes to the surroundings waterways and the beaches, creating unhygienic conditions and polluting the

coastal environment.

These non-point (agriculture, urban sewage) and point (industries, tambak) sources of organic matter all end up into the coastal system. Because of its enormous water mass, currents and tides, the sea dilutes and distributes this man-made pollution. But the absorbing capacity of the sea has limits. Organic pollution creates increased oxygen demand and increased nutrient levels, turbidity, and contamination with pathogenic microorganisms. One of the first changes visible in the near coastal waters of the Mollaca Straits is the increased occurrence of red tides (Chua, et al, 1997). Red tides —or the growth of harmful algae— have also been reported for the area south of the PT Brasadena shrimp farm (large 8,000 ha) and further south along the coast at Labuan Maringgai (Binnie and Partners, 1994). This algae bloom had reportedly caused massive kills of shrimp in the brackish-water ponds, but the CRMP field team could not confirm this. Marine algae bloom is a major indicator of eutrophication of coastal waters, and such events have killed fish and generated paralytic shellfish poisoning in humans eating contaminated shellfish.

The last land-based source of pollution to be introduced in this report is pesticides used in agriculture. Only limited data could be obtained about this, including the preliminary inventory done by UNILA for the Rawa Sragi project (UNILA, 1991). The CRMP field team did, however, interview a large number of farmers from coastal communities, which gives a fair indication of the pesticides used. **Table 4** list the chemical used in brackishwater shrimp farming and agricultural pesticides, based on interview with farmers, observations in agricultural supply shops, and information from reports.

Table 4. Pesticides used in agriculture and brackish water shrimp farming in Lampung

No	Name	Percentage(%)	No	Name	Percentage (%)
1	Diazinon	10,4	16	Reacsal	1,5
2	Phosphit	3,0	17	Lestari	1,5
3	Fastax	16,4	18	Temix	1,5
4	Matador	13,4	19	Tirax	1,5
5	Thiodan	7,5	20	Sipin	1,5
6	Urea	9,0	21	Gandasil	1,5
7	Akoda	4,5	22	Klerap	1,5
8	Dursban	1,5	23	Sepraks	1,5
9	Round-up	1,5	24	Cuarter	1,5
10	NPK	1,5	25	Mipecin	1,5
11	Darmasan	1,5	26	Curator	1,5
12	Gramoxon	1,5	27	Gycap	1,5
13	Indo-bas	1,5	28	Sampone	1,5
14	DMA-46	1,5	29	Suprasid	1,5
15	Cinone	1,5			

Source: CRMP Survey, 1998

Marine Water Quality

Basically three groups of marine waters have to be distinguished based on the principal differences in oceanography and position: (i) east Lampung's shallow waters (5-20 m) with a low-energy coast, dominated by both the currents (southern) and water mass from the Java Sea, and with a relative high but natural input of sediments; (ii) south Lampung with a combination of strong currents generally towards the south-west, protected bays with moderately shallow (20-100 meters) and clear waters fed by the Java Sea, which has supported the growth of coral reefs and seagrass meadows;

and (iii) west Lampung with deep (>100) and clear waters heavily influenced by the Indian Ocean, often with strong currents and wave impact.

Unfortunately, comprehensive studies have been done only for the south coast, particularly for Lampung Bay and Semangka Bay (BAPPEDA, 1997). A complete set of chemical and physical measurements was taken at 10 locations in the northern section of Lampung Bay (Teluk Betung) in May - June 1997. Vertical water transparency, measured by Secchi disk, was found to range between 1.13 and 5.55 meter, which is rather low. Indeed, the water samples showed an average level of TSS of 11.01 to 13.49 mg/l. This is slightly above the Recommended Maximum Allowable Level of 10 mg/l for near coastal waters, as set for ASEAN waters (Watson, et al., 1993). The water samples taken on 20 June (av. 6.89 mg/l) all had TSS levels of about 55% below those taken at 22 May (av. 15.93 mg/l). This shows the great variation in water quality within the bay over short periods (BAPPEDA, 1997).

The data show a clear correlation between water transparency and the level of suspended solids, which consists of terrigenous sediments brought in by rivers and non-point soil sheet-erosion from the degraded hills along the Bay, and from suspended organic matter, such as algae and mucus from the polyps of the hard corals. The relatively low water transparency, combined with only slightly elevated levels of TSS, indicates that organic matter, rather than suspended soil particles, reduce water transparency. This in turn could indicate eutrophication with organic matter from industries, urban centers (sewage), agriculture or brackishwater shrimp ponds found along this coast near Bandar Lampung. This was also suggested as a probable cause during a field visit and scuba diving on 12 May 1998 showing the high level of suspended particles consisting of mucus and algae (M. Zieren, pers. obs.).

Pollution with organic matter is also shown in the rather low DO levels, averaging between 4.82 and 5.17 mg/l. The lowest values measured were 3.2 mg/l, with most stations only reaching a maximum of about 5.6 - 6.1 mg/l. Clean, non-polluted sea water has DO values of at least 6.5 mg/l. Evidence of eutrophication is also found in the rather high BOD levels measured, with an average of 46.6 mg/l (range between 4 mg/l to 86 mg/l for 40 samples taken). Non-to slightly-polluted sea water has BOD values of less than 5 mg/l. The values found indicate that the waters of the bay are very heavy polluted, most probably with organic wastes from sewage and tambak operations (BAPPEDA, 1997). It is important to remember that practically none of the urban centers along this coast are serviced with wastewater treatment facilities, although more than 2.7 million people live here (Bandar Lampung, South Lampung).

Marine water pollution is said to be one of the reasons that the pearl oyster farm of PT Kyoko Shinju, located in the northwest Lampung Bay, has started a second farm in the bay near Pulau Sebuk (Marizal, pers. comm.). The main threats are possibly the nearby tambak, urban pollution from the city, and beach reclamation projects.

Analysis of concentrations of heavy metals such as mercury (Hg), lead (Pb), cadmium (Cd), copper (Cu), and chromium (Cr) shows that most stations were well above the allowable levels of these pollutants, as recommended by the Ministry of Environment (KepMen No 02/MENKLH/I/tahun 1988; BAPPEDA, 1997). Pollution from these metals indicates the presence of wastewaters from chemical or metallurgic industries. No data could be obtained on the types or location of these industries along the coast. However, further evaluation should be done on these findings in association with the recently-developed Recommended Maximum Allowable Levels set for heavy metals in near coastal waters, as based on the ASEAN Project on Marine Water Quality and Monitoring (e.g. Watson, et al., 1993). As an example: Cu levels in Indonesian and Malaysian waters are generally high

as a result of natural processes and geology, while even slight concentrations of Hg, Pb, Cd and Cr have to be viewed as pollution. Some of the previous standards set by LH appeared to be too high, others too low, and new values have been developed which better reflect the local circumstances of Indonesian seas.

The industrial sector of Lampung showed an average growth rate of 8% annually before present economic crisis, which suggests a likely increase in cargo and other shipments. Intensive cargo and other shipments to and from Lampung Bay have already increased the risk of oil pollution, mainly from ballast and waste motor oil. The beaches of Mengkudu, Merak Belatung and neighbouring locations were reportedly polluted with tar balls, probably originating from ships which dump these waste oils at sea (BAPPEDA, 1998).

Swamp and Coastal Zone Hydrology

Tidal system: Tides along the west and south coast are of the mixed prevailing semi-diurnal type, with high water and low water peaks generally twice a day, but with different amplitude and duration. The maximum tidal range measures about 130 cm, with a LLW of 10 cm above mean sea level and a HHW of 140 cm above mean sea level. The tidal range is slightly higher along the northern section of Tulang Bawang and Mesuji, where it measures around 160 cm. This implies that any mangrove greenbelt should be between 208 meters (east coast) and 232 meters (south and west coast) wide at a minimum, taken from the lowest tide level (Keppres 32, 1990 Kawasan Lindung).

Tides are an important feature of the coastal zone because they determine the width of beaches and mangrove swamps, and affect the depth of saline water brought into the rivers with the tides. This is the case particularly in the lowland swamps along the east coast of Lampung, as at Mesuji-Tulang Bawang where brackish water extend upriver to about 40 km (Giesen, 1991; Binnie and Partners, 1994b). Tides also affect the flow of rivers in their lower reaches, such as at Way Pedada or Way Kambas, which have almost stagnant water during high tides. The location of agro-industries along Way Pedada is therefore inappropriate because the low flow volumes can not handle the wastewaters from the factories, and serious water pollution and fish kills are the direct result.

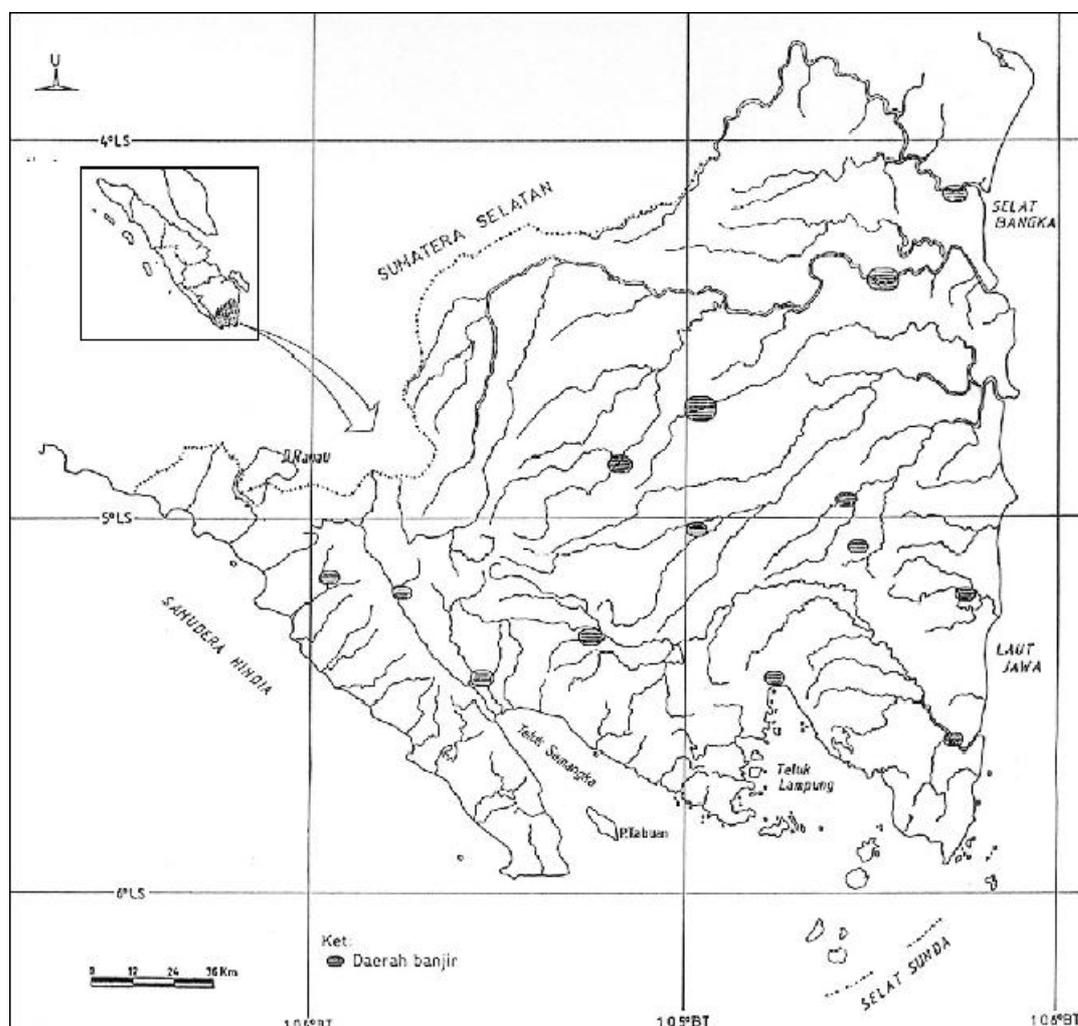
Flooding: Flooding is an annual but natural feature in the coastal swamps and more recently at a number of locations where the natural drainage system has been disturbed (e.g. in urban centres). Although most of the freshwater swamps have been drained and converted into sawah and other types of agriculture, many remaining wetlands flood annually during the rainy season. By storing excess water during heavy rain or river peak flows and gradually releasing this during the dry season, the swamps have a strong regulating effect on the local hydrology.

Typically, swamps along the coast, such as in the Way Kambas N. P., become inundated to a depth of about 1 to 2 meters during November and remain flooded until at least March (Chambers, et al., 1990). Some inland swamps, including Rawa Bakung/Tenuk (about 8,500 ha) close to Manggala, reach their peak floods in January during the height of the West Monsoon, and were reported to reach a depth of 3 meters in only ten days. If these swamps were protected against flooding, e.g. by dikes or drains, the effects would be felt downstream, possibly with the inundation of previously unaffected agricultural land and urban centers (Binnie and Partners, 1994b).

Figure 2 shows the flooded areas recorded for 1992-1995. It can be seen that serious flooding occurred inland from the Way Kambas N. P. and in the upper and middle catchment of the Semangga River, where logging has seriously impacted the hydrology of protection forests. Nor have urban environments, including the areas in and around Bandar Lampung, been protected from regular

flooding, which is caused both by forest destruction in the hills as well the obstruction of the natural drainage by construction of roads and other infrastructure.

Figure 2. Location of impacted sites due to regular flooding
(Source: Internet site of Ministry of Public Works, 1998)



River watersheds are increasingly degraded as protected forests are converted into agriculture with cropping systems do not apply soil conservation measures as required on the steep hills. Areas of forests are cleared daily in the Bukit Barisan N. P. by migrants from Java, presumably to convert into coffee and cacao plantations (Bpk Tony BAPPEDA, pers. comm.). Degradation of the river watersheds has probably already disturbed their hydrology, as suggested by the fluctuating debit levels of the rivers. Increased soil erosion and higher peak flows of rivers from degraded watersheds may result in floods in downstream areas.

Saltwater intrusion: The intrusion of saltwater into coastal land has been reported as an increasing problem in coastal communities that depend on good groundwater as a source of potable water. For instance, the area between Ketapang and Kuala Penet along the east coast is said to be affected by saline ground water up to 2.5 km inland. The wells in at least 18 villages presumably had good water, but are now brackish or even saline (BAPPEDA, 1998). The fact is that more than 90% of the mangroves along this 70 km coast have been lost and converted into tambak. Although mangrove-shrimp pond conversions are seen as the sole source of the increased level of saltwater intrusion, excessive extraction of ground water for drinking, tambaks, and agricultural use might play a much more important role. Additionally, many rice paddies and former freshwater swamps have been

converted into shrimp farms or built-up areas, which as a result has greatly reduced the area for groundwater recharge from surface water and precipitation. Fieldwork by the CRMP team along the east coast revealed, however, that few if any of the community's wells have changed in water quality due to reported saltwater intrusion (Bpk. Ali Kabul, UNILA, pers. obs.). Any brackish water found was related to the siting of the well in a naturally brackish water environment, such as previous mangrove swamp or along the creeks and drainage canals (e.g. to Rawa Sragi).

JITU and PITU transmigrant schemes in the former freshwater and peat swamps along the Tulang Bawang and Mesuji have shown some of the problems associated with swamp reclamation. According to locals, saline intrusion in the Tulang Bawang River reaches almost to Gunung Tapa village (40 km inland) if the dry season lasts at least three months. Groundwater in the southern part of JITU was found to be too saline to drink, suitable only for washing (Giesen, 1991). To obtain potable water, the thousands of transmigrant families use rainwater or buy water, which is brought in from the remaining freshwater swamp reservoirs upstream on the Pedada and Tulang Bawang rivers. The problems with saltwater intrusion are expected to increase as more swamp land is reclaimed, agriculture intensification programs consume more river water for irrigation, and the anticipated continued degradation of river catchments leads to higher peak flows and lower low flows of the rivers. The cumulative effect of this will be that less water will remain for groundwater recharge in the lower reaches of the river system and its associated swamps, leading to increased saltwater intrusion along the coast.

Much of the coastal area in Lampung is still without the services of the public water company and depends entirely on locally available ground or river water; or in the worst cases when these are unsuitable for drinking, on the collection of rainwater in drums and other containers. It is clear that coastal communities will be greatly disadvantaged if ground and river water quality declines due to inland developments. Economically stronger groups in society usually build deep wells (down to 150-200 m), such as PT DIPASENA at its Tambak Inti Rakyat project, but this is impossible for the majority of the people in Lampung.

V. Freshwater and Peat Swamp Forests along the Coast

Historic and Present Distribution

Lampung had considerable areas of freshwater swamp forests along its east coast, but today almost all have been logged, drained, or converted, mostly for transmigrant agriculture schemes. All swamps are closely associated with the major rivers draining into the Java Sea and have to be considered as part of the coastal management zone. Well known swamp reclamation schemes include the JITU and PITU transmigrant sites in Tulang Bawang and the Rawa Sragi along the estuary of the Sekampung River in the south.

The remaining area of swamp in Lampung until about 1986 consisted of 13,400 ha of peat swamp forests, 41,200 ha of freshwater swamp forest, and 153,200 ha of marshes (RePPPProT, 1988). The extensive areas of marshes are mostly found inland in the mid-watershed of rivers such as the Tulang Bawang, and constitute the annually-inundated floodplain and reservoirs close Manggala. Giesen (1991) calculated that almost 75,000 ha of freshwater swamp occurred in the lower coastal plain of the Tulang Bawang River, based on interpretation SLAR images. Previous estimates by FAO estimated a total area of 400,000 ha of swamp forests, with no peat swamps identified (Whiten et al., 1987). The reason for this is probably that peat soils are relatively thin (1-2 meters at a maximum), and are therefore grouped under freshwater swamp forests. Most of the peat has gone now, due to drainage, cultivation, and burning in the swamp reclamation schemes. The Pedada River, which in

1990 carried mainly black peaty water, has turned into a brown water river loaded with suspended sediments since the massive reclamation in its catchment area (Giesen, 1991; Rusila Noor, et al., 1994).

As recently as the 1970s uncontrolled migrants mainly from South Sulawesi (Bugis), South Sumatra, and East and Central Java, settled along the swampy coast. Although most of the settlers were rice farmers, swidden cultivators, or fishermen, some started brackishwater fish ponds, particularly in the Rawa Sragi area. The first large scale, government-sponsored swamp reclamation program started in 1981 under the Mesuji reclamation scheme, and by 1986, 7,000 ha had been prepared for cultivation under the JITU scheme. Primary drainage canals for PITU (Tulang Bawang) were constructed in 1988, followed by land clearing in 1989, and the first transmigrants arrived in 1990. The Rawa Sragi reclamation scheme started in 1982, which focussed on sawah in backswamp areas and land reform schemes. The government programs have converted a total of 51,500 ha swamp land: 20,000 ha in JITU, 11,500 ha in PITU, and 20,000 ha in the Rawa Sragi scheme. An additional area of unknown size has been reclaimed from the swamps north and south of the Mesuji River, part of which is in Lampung and the remainder in South Sumatra.

Not all of these have been successful in sufficiently raising the living standards of the migrant families involved, mainly due to serious problems with acid soils and saltwater intrusion in these former swamps. The JITU and PITU schemes support only one rainfed rice crop per year, and many farmers are trying their luck in more lucrative work. Conversion of sawah to tambak has been one of the most dominant processes seen along the east coast. Estimates indicate that more than 2,000 ha of sawah may have already been converted into tambak (Zainal, 1998). Rawa Sragi belonged to one of the most successful swamp development schemes in Indonesia, but bad maintenance has seriously affected its rice production (Wicher Boissevain, pers. comm.). Of the total of 1,350 ha of sawah developed for the land reform programme in Desa Karyatani and Bandar Agung (both Rawa Sragi), more than 57% (772 ha) has been converted into tambak. This is particularly sad because the Rawa Sragi project has seriously attempted to protect a large mangrove belt along the coast, combined with significantly increasing the welfare of coastal farmers with the production of sawah. Several of the shrimp farms on former sawah land have production problems related to the lack of sufficiently saline water, which inhibits the growth of the adult tiger prawns.

Interpretation by CRMP of the newest acquired TM imagery (1996-1998) shows that about 100,000 ha of heavily degraded or secondary swamp forest remains in Lampung, mainly along the Tulang Bawang and Mesuji rivers and in the Way Kambas N.P. No primary swamp habitat, either freshwater or tidal mangroves, has survived in Lampung. Figure 3 gives an overview of the major swamp habitats found along the coast of Lampung.

Most swamp reclamation has taken place since the early 1980s, while the real boom in sawah and mangrove conversion to tambak taking off in 1988. With the present strong market prices for prawn and the continued support of the government for this sector, more sawah will be lost to tambak, and the last small areas of mangroves will also be converted.

Flora and Fauna

Flora: The flora of the remaining freshwater swamps along the coast have been very seriously impoverished, but still supports a surprisingly diverse fauna, mainly fish and waterbirds.

As mentioned previously, no primary and late-secondary swamp forest remains in Lampung. The most dominant vegetation types found in the formerly 75,000 ha of lowland coastal swamps in the Tulang Bawang area consist of (Giesen, 1991):

- i. *Melaleuca cajaputi* (Gelam) dominating the secondary swamp woodland,
- ii. rice paddies of various transmigration projects,
- iii. *Mimosa pigra* swamp shrub land,
- iv. freshwater pools and open water with aquatic plant species.
Observations in remaining swamps in Way Kambas indicate the following additional swamp types along the coast (Chambers, et al., 1990; Hapsoro, 1995):
- v. Deeply flooded grass and sedge swamps, mixed with some remains of heavily degraded swamp forests.

More than 90% of the coastal swamps of the Tulang Bawang consisted of Gelam (*Melaleuca cajaputi*). The widespread occurrence of *Melaleuca* secondary swamp forest indicates past mismanagement since this species is very often found to invade freshwater swamps and shallow peat swamps after they have been logged, drained, and also often burnt. A good example of this process is found in the Padang Sugihan reserve in South Sumatra, where after the establishment of drains, annual fires invaded this primary swamp forest habitat. Only within a period of 10 to 15 years, all specific swamp trees were lost and replaced by a near-monotypic vegetation of *Melaleuca* and sturdy grasses and ferns. The major cause for concern is that these forests do not yield any valuable wood (other than some cheap poles), and have a very low value as wildlife habitat. The frequent problems with elephants of the Padang Sugihan reserve roaming off-site in search for better sources of food is an illustration of this.

Gelam forest attains a height of only about 10-12 meters, and also include trees such as *Barringtonia acutangula*, *Dillenia* sp., *Lagerstroemia speciosa*, *Licuala paludosa* and *Sapium indicum*. The undergrowth consists of sedges *Cyperus halpan*, *Eleocharis ochrostachys*, *Scleria sumatrana* and *Thoracostachyum sumatrana*. Fern species include *Lygodium microphyllum* and *Stenochlaena palustris*. This habitat is very susceptible to forest fires in times of drought. This was very clearly demonstrated during the several months of massive forest fires in southern Sumatra and Kalimantan in the second half of 1997 which received worldwide press coverage because of its massive impact on the region's people, wildlife, forests and air quality. BAPPEDAL maps indicate several previous forest fires in the swamps of the Tulang Bawang and Mesuji areas (source: BAPPEDAL Internet site).

Degradation of swamp forests in seasonally inundated areas has resulted in two vegetation types: *Mimosa pigra* swamp shrub land, and grass and sedge swamps. Both types are combined with open water/small lakes in permanently inundated sites, with typical aquatic vegetation, such as lilies, water hyacinth, and duck weed.

Mimosa pigra swamp shrub land is found southeast of Manggala, south of the Tulang Bawang River. Many tree and shrub species remaining are the same as those in the riparian forest, such as *Barringtonia acutangula*, *Gluta renghas* and *Lagerstroemia speciosa*. Other species, such as *Fagraea fragrans*, *Licula paludosa* and *Pholidocarpus sumatrana* are typical of swamp forests. The dominant species is, however, the giant mimosa or putri malu (*Mimosa pigra*), which is an exotic plant accidentally introduced to Indonesia from South America (Giesen, 1991).

The typical grass and sedge swamps are found extensively in the coastal plain of Way Kambas N. P., and were formed after repeated logging and burning during dry seasons destroyed the primary swamp forests. Inundation of these swamps starts in November during the monsoon and reaches its peak of between 1-3 meters of water in January. Water levels then drop until late April. The flora is dominated by high grasses (rumput gajah), primarily *Isachne globosa* and *Bracheachne* spp., mixed with

Paspalum spp., and with alang alang (*Imperata cylindrica*) in the dryer areas. In the wettest parts close to river banks, various sedges grow with *Heleocharis* spp., *Eleocharis* spp., *Scleria* spp. and *Sciripis* spp. and *Cyperus* spp. The margins of these swamps are bordered with remains of swampy shrubland where *Pandanus* spp., *Melaleuca cajuputih*, *Nauclea* spp., *Melastoma* spp., *Oncosperma tigilaria*, *Cyrtostachys lakka*, and the occasional *Gluta renghas* grow.

The sawah all covers former freshwater swamps, which due to the available water resources and their typical heavy and compact gley-soils, are very suitable for growing wetland rice. Part of the coastal paddy fields have recently been converted into brackishwater shrimp farms, reportedly covering at least 2,000 ha to date (Zainal, et al., 1998).

Fauna: Outside the protected area of Way Kambas few mammal species survive, though historically these sites were known to be as rich as many of the famous wildlife areas elsewhere in Sumatra (e.g. with Sumatran Rhino, Tapir, Sumatran Tiger, Elephant, etc.). Small populations of monkeys survive in the riparian forest and probably in the gelam and other swamp forests of Tulang Bawang, with populations of silvered leaf monkey (*Presbytis cristata*) and long-tailed macaque (*Macaca fascicularis*), and possibly pig-tailed macaque (*Macaca nemestrina*), sambar deer (*Cervus unicolor*), and wild pig (*Sus scrofa* or *Sus barbatus*). It is, however, only a matter of time before these species disappear as well, due to habitat loss and hunting, with the possible exceptions of the wild pig and long-tailed macaque.

Way Kambas was established as game reserve by the Dutch administration in 1937 and upgraded to National Park in 1989 by the Ministry of Forestry. However, the area fell victim to commercial logging between 1968 and 1974. This was followed by eight years of illegal logging by local people. The effects of these two periods of timber exploitation combined with the invasion of agricultural settlements and repeated forest fires have completely altered the natural forest vegetation. Despite this, the area is still surprisingly rich in wildlife, and contains all key wildlife species characteristic of lowland Sumatra, with at least 37 mammals, including elephant, tapir, Sumatran rhino, Sumatran tiger, sun bear, sambar and barking deer, two otter species and eight species of primates. Both the rhino and tiger are closely monitored by the internationally-sponsored Proyek Tiger and Proyek Rhino. Recent inventories using infrared cameras proved that the population of Sumatran tiger is much larger than previously thought. At least six tigers are resident in the area and, more importantly, 15 tigers frequently use or pass through the area from neighboring lands, which indicates the importance of wisely managing the surrounding forest areas. Tigers, tapirs and rhinos prefer the swampy habitats along the coast.

The natural swamps along the coast have been heavily impacted by economic development, impoverishing both flora and fauna. But this does not entirely apply for the diversity of birds and fish, as proven by the rich array of species found in both the Way Kambas and Tulang Bawang swamps. Way Kambas N.P. is a real birders' paradise with at least 300 species of birds (Jepson, 1997; Himbio, 1995). Famous water birds using the coastal swamps include the endangered white-winged wood duck (*Cairina scutulata*), the rare Storm's stork (*Ciconia stormi*), the vulnerable milky stork (*Mycteria cinerea*), the vulnerable lesser adjutant (*Leptoptilus javanicus*), and the Pacific Reef Egret (*Egretta sacra*). All these species are protected under Indonesian law. The area is one of the last strongholds of the white-winged wood duck, with between 24 and 38 birds, the largest population left of this treeduck in Sumatra. Unfortunately, Way Kambas is not safe from negative impacts to habitat and fauna. Regular forest fires, intensive illegal poaching of fish in the coastal swamps, hunting of duck, and infrastructure development in support of tourism are taking their toll on the white-winged wood duck.

A short survey of the Tulang Bawang identified 88 bird species from 33 families (Rusila Noor, et al., 1994). Two rare and two endangered species (or vulnerable, according to the IUCN Red Data Book) and 16 species listed in CITES were amongst those recorded. The swamps also support one of the largest water bird colonies in Indonesia, includes the first known breeding site in Sumatra for black-crowned night heron (estimated 1,677 pairs), and Oriental Darter (48 pairs); the second and largest colony known in Sumatra for Javan pond heron (30,338 pairs), and one of the most significant breeding sites for great egret (1,202 pairs). This indicates how extremely diverse and ecologically important these coastal swamps were for Lampung and Indonesia, and probably still are. The fact that the ornithological sites cover the inland floodplains of the Tulang Bawang does not reduce their significance for coastal management programs, as many of the birds feed in the rice paddies, mangroves and mudflats along the coast, as well as in the tambak. Annex I shows the location and the proposed conservation status of the swamps with their bird colonies.

The colonies are heavily exploited by local fishermen and transmigrants for eggs and young birds as food, and the reported cutting of trees impacts the birds. This will undoubtedly diminish the colonies' present numbers. Development of community-based management is urgently required because all sites are owned and used by local fishermen, who report higher than average fish catches in the swamps visited by birds.

Fish diversity is also high in the Tulang Bawang system, with at least 88 species identified in six days' survey (Rusila Noor, et al., 1994). Would the brackish water estuary and the many streams in the upper watershed were included, considerably higher numbers of fish species would be found. Four fish species protected by Indonesian law occur in this area. Both are significant for the people of Lampung for food and their aesthetic value: two species of belida (*Notopterus chitala* and *N. borneensis*), the arowana (*Scleropagus formosus*), and the bala shark (*Balantiocheilos melanopterus*). Nearly all of the 88 species are eaten locally or are found on the menu of the specialty fish restaurants in larger towns in south Sumatra. The inland fisheries in the rivers and associated swamps are very productive, representing about 45% of the total fish catches in Kab. Tulang Bawang (marine and freshwater). The fisheries are very important for the original coastal inhabitants and the transmigrants as a source of income and food, particularly in times of hardship (e.g. the prolonged dry season of 1997). Pollution of river water by the many agro-industries is still the largest threat to fisheries and often resulting in mass fish kills.

The coastal swamps support a reasonably large number of reptiles and amphibia. There are at least 20 species, including small populations of estuarine crocodile (*Crocodylus porosus*) in the Tulang Bawang swamps, false gavia (*Tomistoma schlegelii*) in Way Kambas, and monitor lizards (*Varanus salvator*) and phytons (*Phyton reticulatus*) all along the coast. All four species have become rare because these are intensively hunted for their skin.

Function and Benefits

The freshwater swamps are of prime environmental, ecological and economic importance. These are the major benefits and functions:

- The swamps absorb enormous amounts of floodwaters and precipitation during the rainy season from November to April, as can be clearly seen on satellite imagery. Without this hydrological buffer, floods downstream along the lowlands of the coast might very likely increase in frequency and intensity (depth of flooding), potentially affecting tens of thousands of families;

- The swamps are of prime significance to inland fishing, with 80% of catches coming from the marshes and 20% from the river. Total inland catches in the Tulang Bawang watershed constitute 45% of the total fisheries catch in Kab. Tulang Bawang. It is a very important source of protein for an increasing population. Locals reported that fishing is more lucrative than the traditional cultivation of rice in the levees and shallower swamps along the Tulang Bawang River (Rusilia Noor, et al., 1994);
- The freshwater sources of rivers and associated coastal swamps are very important for the recharge of ground water and in keeping saltwater from intruding into coastal land. A stable hydrology is probably more effective in halting saltwater intrusion than a mangrove greenbelt along the coast.
- The swamps also supply potable water to communities along the coast where ground water is polluted with acids from PASS and saltwater, and where no public water supply systems exist. Government intensification programs for rice production require ample availability of freshwater for irrigation, which is supplied by rivers and swamps. River debit levels vary greatly through the year, increasing the importance of swamps for additional water supply.
- The inland and coastal swamps represent very significant wetlands of importance to wild life conservation, both national as well as international (RAMSAR). In view of the importance of these swamps for water bird conservation, it is recommended that Rawa Tenuk, Rawa Bungur, Bawang Belimbing and Bawang Lambu Purus as a Wildlife Reserve, and the water bird colonies in Rawa Pacing and Rantau Kandis as Strict Nature Reserves (Rusila Noor, et al., 1994).

Threats

The most visible threat to the system of rivers and swamps is the ongoing pollution from effluents discharged by a great number of agro-industries. Water pollution leads annually to mass fish kills in the rivers (but not the swamps), impacting the fishing communities. Programs such as Prokasih have greatly enhanced the waste management procedures at a selected number of factories, but treatment systems are still inadequate for many, and industrial growth is increasing the total pollution load of rivers. Water pollution is also increasing as watershed degradation increases the suspended sediment loads carried by river water. Some rivers in the Way Kambas and Tulang Bawang swamps have changed from typical, peaty blackwater streams into murky brownwater rivers as a result of agricultural activities in the catchments (Chambers, 1990; Rusila Noor, 1994). Along with overfishing and destruction of breeding habitat, this change in water type has led to a scarcity of fish such as arowana and belida. Both species may easily become extinct locally as a result. Use of fish poisons such as Endrin have also been reported in rivers in Way Kambas and the Tulang Bawang swamps.

The lack of ownership in the present auction systems of 'lebung lebak' does not encourage proper, sustainable management of fish resources. It leads instead to overfishing and degradation of fish habitat. The granting of local ownership (e.g. rights to fishing areas) could be contractually linked to obligations of reserve management of both fish resources and the nationally-important water bird colonies (e.g. banning of egg collection and hunting). This would be more advantageous for locals and provide incentives for proper resource management.

Drainage is clearly the largest threat to the remaining wetlands, but no data exist on the present trend with regard to conversion into sawah or other land use by local communities. The swamps of Bawang Lampu Purus are, however, part of the ongoing irrigation development program by Public

Works (BP2SDA), called the Quick Yielding Schemes program. This program would be in conflict with the proposed conservation management of the area.

The Gelam swamp forests are very susceptible to fires during the dry season. The massive forest fires of 1997 are still in everyone's mind and have seriously affected the health of local people and killed an unknown amount of wildlife. Fires inhibit forest regeneration, destroy wood resources, and change the composition of vegetation. It is very important to avoid the recurrence of fires with proper warning systems and quick action to stop any fires from expanding into additional forest areas.

VI. Seagrass and Seaweed Fields in Shallow Coastal Waters

Only field work can determine the regional distribution of seagrass and seaweed fields along the coast of Lampung, assisted by the interpretation of satellite imagery. None of this has been done so far and therefore little can be reported on the habitats. Some literature exists for Lampung Bay on seagrass (Kiswara 1991b and Prawoto et al. 1992, in Tomascik, et al., 1997).

Seagrass beds are found in the area of Legundi Island in the southwestern part of the bay on the intertidal reef flats and on the sandy reef slopes down to a depth of about 8 m. Seven seagrass species have been identified so far: *Enhalus acoroides*, *Cymodocea rotundata*, *C. serrulata*, *Halophila ovalis*, *Halodule univervis*, *Syringodium isoetifolium* and *Thalassia hemprichii*. Species composition is similar to that found at Banten Bay (Miskam Bay) on the other side of the Sunda Strait, suggesting that other locations along the south coast of Lampung will show similar communities of seagrass. The plants grow primarily in the sand and coral rubble sediments, with a soil depth varying between 5 to 40 cm. Seagrass communities vary from mixed to monospecific meadows, with cover ranging between 5% to 80%.

Seagrass beds are important nursery grounds for fish, including many of the groupers (kerapu) so characteristic of coral reefs (Sugama and Eda 1986 in Tomascik et al., 1997). Seagrass is also the staple food for Dugong (*Dugon dugon*). There are no reports with regard to its occurrence in Lampung, but a small resident population apparently survives in Banten Bay (M. Zieren, pers. obs., 1992).

Seagrass meadows may also be found in Semangka Bay, though restricted to the narrow border of shallow water along the coast and fed by the considerable input of muddy sediments from rivers such as the Semangka. The bay reaches a depth of more than 200 m a few kms offshore, which precludes the growth of seagrass. Field inventories by CRMP will have to assess the situation.

A slightly better picture is available with regard the distribution of seaweed. It has considerable importance in Lampung for local communities, who harvest it from the naturally occurring seaweed meadows along the coast. Between 31 ton and 430 ton were exported annually between 1992 and 1996 (BPS, 1997). A modest start has been made with the artificial cultivation of seaweed, which is hoped will compensate for the losses in production of degraded natural areas, such as experienced along the west coast and the Tj. Belimbing peninsula. Seaweed is widely distributed along the coast except along the east, with the largest fields and production along the west coast down to Tj. Belimbing and Tj. Cina in the south. Further details on species, use, and distribution can be found in the paper on mariculture resources (Marsden, 1998, in prep.).

VII. Coral Reefs

Distribution and Area

Coral reefs in Lampung are mainly found along the south and west coast as fringing reefs of the mainland and around the 60 or more islands found in the southeast (Bakauhuni), Lampung Bay, and the southeastern shores of Semangka Bay. The best reef development is probably in west Lampung, but no field data exist to accurately determine the reef communities, seaweed meadows, and other type of benthic life. Reefs also growing on the rather unstable shores of the Krakatau volcanic islands located in the middle of the Sunda Strait. Satellite imagery shows that the whole west coast is fringed by a small margin of reefs, which at a number of locations have developed into rather broad systems, particularly along the shores at Lemong, Walur, Biha, Wayjambu, Siging, and probably in the south at Tj. Belimbling. Reefs are also found around the shores of Betuah and Pisang islands.

Surprisingly, some aggregations of coral boulders have been identified along the swampy mangrove coast in the east, particularly in the northeast (Tulang Bawang, etc.)(CRMC,1998). It is not known if these cover the dead remains of former coral reefs from times when the shoreline was located much more inland, or are just emerging rock formations. It is quite possible that they represent the outer reef boundary of the Pulau Seribu group, including Pulau Segama, 20-25 km east of S. Penet. pulau Segama is included in the provincial territory of Lampung, though few people realize this.

Reef Type and Biodiversity

Most reefs in Lampung are fringing reefs, which means that they grow on top of the submerged margins of the shoreline of the mainland and islands. But LIPI, in a short study on Lampung Bay, indicates that there are both fringing and patch reefs (Kiswara, 1991b in Tomascik et al., 1997). Indeed a number of the reefs in Lampung Bay identified from TM satellite imagery are typical patch reefs with sandy cays (core of island). Patch reefs among those found in the concession of the Kyoko Pearl Farm in Teluk Pedada and close to Pulau Tegal,. Reef flats of the fringing type are relatively narrow (20 - 60 m wide), and reef growth stops of about 10 - 17 meters, where the slope continues as mud or sand flats. Local circumstances related to water quality, substrate and oceanography have influenced the community structure and growth potential of reefs.

Coral communities around Sertung, Rakata and Rakata Kecil islands of Krakatau have colonised relatively unstable substrates, ranging from coarse loose sand to large but equally loose basaltic rocks (Tomascik, et al., 1997). Reef slopes facing Anak Krakatau are usually gentle and sheltered, while the seaward slopes are steeper and mre exposed. The reefs have been reported as recovering rather slowly from the latest eruptions (1883 and 1993), which is directly related to the lack of suitable substrate and the frequent occurrence of local earth tremors. Particularly sensitive are the 'tabulate' and 'corymbose' lifeforms of *Acropora* hard corals, shown in the common occurrence of overturned colonies. Many of the reefs therefore have an abundance of small diameter acroporids, suggesting the frequent impacts of earth tremors which prevents colonies to grow bigger than 50 cm in diameter, even though colonies of these species are known to attain diameters of 2-3 m. A similar situation exists on the reefs of nearby Pulau Peucang, facing Ujung Kulon on Java, where reef community structure is also influenced by the frequent underground tremors, preventing colonies from attaining their maximum size and influencing the composition of species (Tomascik, et al., 1997).

The 1883 eruption of the Krakatau, with its subsequent Tjunami waves, undoubtedly destroyed a large part of the reefs in the Sunda Strait, as illustrated by the large coral boulders found hundreds of meters inland along the coast of Carita (West Java), but the occurrence of 2-3 meter coral colonies also indicates that some reefs survived this impact. One hundred years after the eruption of Krakatau, coral development remains marginal in the area. Nonetheless, about 213 hard coral species have

been recorded from the various islands in Sunda Strait and Lampung Bay (Sukarno and Suharsono, 1983 in Tomascik, et al., 1997). This is comparable to the 193 species found in Pulau Seribu (Suharsono, 1998).

Although this indicates relatively diverse reefs, comparison with a previous study (Salm, et al., 1982 in Tomascik, et al., 1997) suggests locally impoverished reefs and a high level of habitat heterogeneity in Krakatau. Average species richness per location was only 48.6 (STD 9.2) which is considered rather low. The cumulative list gives a total of 113 scleractinian coral species for Krakatau Islands (see **Annex I**). Unstable substrates and the impact of the Krakatau Tsunami, combined with ongoing earth tremors could inhibit the further development of the reefs.

No data are available on community and species diversity of the reefs in Lampung Bay or along the west coast. This pitiful lack of basic information on an economically important habitat also applies to reef fish and other fauna groups. This remains as an important task for institutions such as UNILA, LIPI and program such as CRMP.

Reef Condition and Impacts

Inconsistent reports were received from the government regarding reef condition in Lampung Bay (BAPPEDA, 1998; Black, 1998). No previous comprehensive inventories have been done. A n IPB team started with Manta Tow reconnaissance surveys and Line Intercept Transect Inventories, but had to restrict itself due to bad weather to the reefs of Lampung Bay and those of the islands in the southeast (Bakauheni). Unfortunately, this precludes the possibility of presenting an overview of reef condition across the province. Additional but separate work was done on a restricted number of reefs in Lampung Bay. Unfortunately, LITI and Manta Tow data have been modified and mixed, making it impossible to use them (Black, 1998). The Black report lacks the necessary distinction among live coral, dead coral, rubble, dead coral algae, and sand/open patches, which precludes analysis of the possible local causes of degradation.

No precise data are available on the type and size of catches of reef-related fish, although reports of the provincial fishery office describe a steady decline in total catches from Lampung Bay. The brood stock of kerapu and Napoleon wrasse used for mariculture research at the Balai Budidaya Laut (mariculture research station) had to be obtained from the remote Mentawai islands in West Sumatra, indicating the lack of adequate stock in Lampung.

The greatest dangers to the reefs are blast fishing and illegal trawling (Black, 1998; Nevianty, pers com.). Reefs in the outer bay are more heavily impacted by blast fishing than those in the inner bay, often the case with remote islands in Indonesia. Even in the strict nature reserve of Gunung Krakatau, reefs have not been protected. Coral at Rakata showed the clear signs of dynamite as well the impact of trawl fishing. All fishermen involved in blast fishing live in two villages (Teluk Betung and Mutun) and are equipped with 29 blast fishing boats. This should make it relative easy to control (Black, 1998). Good progress has been made in reducing blast fishing through joint operations with the Navy and the local fisheries department.

Less visible, but nevertheless a potential threat to a healthy reef, is the gradual eutrophication of marine waters in the bay (see section River and Water Resources). The reported impacts of coastal developments on the production of pearls of the PT Kyoko farm shows a possible trend of declining water quality. Generally speaking, suspended sediments are not yet of concern to the reefs in Lampung Bay, as most locations had a vertical visibility of more than 5 m (Secchi disk), indicating low levels of TSS.

But interpretation of recent satellite imagery (TM 1998, 1997, 1996) and water quality sampling programs show the generally high load of suspended solids in near-shore waters, including at Teluk Betung (near Bandar Lampung) and the area close to the estuary of the Semangka River in the Semangka Bay. Fieldwork confirmed the deplorable condition of reefs close to the mainland in Lampung Bay (Pantai Pasir Putih, Pulau Condong), where sediments and high organic loads added to the stress imposed by earlier blast fishing (M. Zieren, pers. obs.). Hard coral colonies showed the many dead patches covered with sediment so typical of prolonged sediment stress. Reefs were reportedly still fine up to 10 or 15 years ago when spontaneous migrants from Java starting clearing the steep forested hills above the coastline 1-2 km away. Most of these hills are now in a critical condition from serious soil erosion.

Of concern is also the input of organic pollutants into Lampung Bay from tambak, sewerage, surface drainage from the urban centers along the coast, and possibly from agricultural fertilizer run-off. Water pollution has proven to have disastrous effects on reef condition in the Pulau Seribu archipelago.

The use of the mini-trawl (*lamparan dasar*) in Lampung Bay was reported by the locals as often interfering with their fishing interests. It destroys their fishing gear, damages coral reefs, and indiscriminately harvests whatever is caught in the nets. Most of the trawls come from outside, including Lempasing and West Java (Black, 1998). Not mentioned, but of similar impact in the long term, is the destruction caused by the many years of using and moving *bagans* (stilted fish platforms). Most *bagans* used today are the floating type, but a few still use fixed platforms placed on top of the reef flat with long bamboo poles or along the reef crest to maximise the catch. Dozens of *bagans* are found along each coral island in Lampung Bay and have to be frequently moved to a new spot. Through the years, this has a significant impact on the condition of the reefs.

Widespread reef damage was also observed from boats landing on beaches during low tides. This damage is entirely unnecessary—proper jetties can be constructed or alternative boat landing locations could be found easily.

Reefs of the Krakatau island group are located far enough offshore to avoid the impact of land-based pollutants. However, water quality in the immediate vicinity of Anak Krakatau seems to be marginal, mainly due to the erosion of lava deposits along the shore and the leaching of iron oxides from lava flows, which frequently color the water a muddy brown (Thomascik, et al., 1997).

It is recommended that more surveys be directed at assessing water quality and the possible impact of suspended sediments and soluble organic pollutants on reef conditions. This could be part of the proposed program to assess the impact of urban pollution in Lampung Bay and to develop improved sanitation, sewage and solid waste management systems.

Issues of Importance for Reef Management

Too little work has been done on the reefs to determine in detail where work is needed to improve reef management and use, but a number of more general guidelines can be given.

A. It is clear that the CRMP field survey program has to be expanded to include the reefs of west Lampung and the remaining areas along the south coast (Krakatau, mainland Kaliandra, Semangka Bay, and Pulau Segama along the east coast). The survey should be able to provide answers the

following issues.

Overview Mapping:

- Determine the overall condition of reefs in Lampung (Manta Tow statistics);
- Determine the local condition of reefs (choose both the best and worst sites for LITs; work with life forms); follow the standard protocols of LIPI/COREMAP;
- Determine water quality at each reef sample site (TSS, visibility, organic pollution; for Lampung Bay also include other pollutants, e.g. heavy metals);
- Indicate the use of reefs, fishing grounds and fishery techniques affecting reef resources (not only blast fishing!);
- Identify which individuals and communities are using which reefs; combine these findings with that of the catch fisheries team and that of the 'social-budaya' team;
- Determine how much of reef use and misuse is external (passing 'foreign' fishermen from other provinces, regional water pollution, terrestrial impacts, government-sponsored programs/decisions, etc.);
- Map the existing and potential good dive sites;

Specific/local Mapping:

- Choose a limited number of villages representative of the array of communities found along the coast and try to develop community maps with the residents of coastal resources of importance to a them;
- Identify specific reef management options for each selected village — both reef preservation and improve the income of fishermen. Determine if there would be any local capacity in villages to function as Reef Watchers; similar to functioning as local Village Motivators;
- Initiate reef research, preferably by a local university, dive club or government institution, on sediment and organic pollution at a number of selected reefs by way of fixed sediment traps, detailed water sampling, and measurement of growth rates of hard corals. Determine sources of pollutants/sediments and indicate what local land-based management would be required to significantly decrease this impact.
- Determine the diversity of reef fish, corals, and other macro-benthic fauna at selected reefs using fixed observation points. This research is not solely academic because it quantifies the situation with regard to reef fisheries; helps determine the need for fish sanctuaries to support catch fisheries in the neighborhood; and identifies the real causes of reef degradation (e.g. it may be sediments/eutrophication instead of blast fishing).

B. Based on the above findings, determine what action has to be taken at the local and regional levels to achieve successful local reef programs:

- Improve spatial planning to help avoid government decisions that conflict with wise reef

management and use (e.g. locating potentially polluting industries close to a key area of reef);

- Work with the government on strategic planning to improve the level of consensus on development affecting the coastal zone. Without a shared vision or strategy, little of the Spatial Plan and local community programs will survive macro decisions and processes. For example, a proposed moratorium on further expansion of shrimp farms in Lampung could greatly enhance the control over illegal conversion of coastal land into ponds. Policy decisions on which river systems are appropriate for industrial use and which are not could greatly improve water quality by the placing new agro-industries from small tributaries. The results should be a detailed map of industrial development zones approved by the principal line agencies (e.g. part of the legal documents of the Spatial Plan);
- Develop community-based reef management programs in a selected number of villages, based on selection criteria that include high dependency on reef fisheries; high impact on reefs (e.g. the families involved in blast fishing); high potential for adopting reef conservation and/or ecotourism development, etc.

References:

- BAPPEDA, 1997. Studi Penentuan Status Mutu Air Laut Perairan Pesisir Teluk Lampung. Buku Laporan Akhir. CV Madya Rancana.
- BAPPEDA, 1998. Potensi Wilayah Pesisir Pantai dan Kelautan, Propinsi Lampung. Non published paper.
- Binnie and Partners, 1994a. Southern Sumatra Water Resources Project. Tulang Bawang Feasibility Studies, Final Report, Volume 15, Technical Reports. PU/Binnie and Partners.
- Binnie and Partners, 1994b. Southern Sumatra Water Resources Project. Tulang Bawang Feasibility Studies, Final Report, Volume 6, EIA (ANDAL). PU/Binnie and Partners.
- Black, M., 1998. Report on Marine Resource Use and Potential Tourism in Lampung Bay. Intern Study for CRMP-Lampung (Draft).
- BLH, 1996. Neraca Kualitas Lingkungan Hidup Daerah Propinsi Lampung Tahun 1996. Buku II dan Buku III. Biro Lingkungan Hidup, Pemerintah Propinsi Daerah Tingkat I Lampung.
- BLH, 1995. Prokasi, Program Kali Bersih, Propinsi Lampung, 1995
- BPS, 1997. Lampung Dalam Angka. Kantor Statistik Propinsi Lampung.
- Chambers, A., M. Cousins, S. Hedges, J. Newman, G. Riddoch, A. Webb and S. Wilson, 1990. The White-Winged Wood Duck, *Cairina scutulata*, in the Way Kambas National park, Lampung Province, Sumatra, Indonesia. Southampton University Sumatra Expedition.
- Chua Thia-Eng, S. A. Ross and Huming Yu (editors), 1997. Malacca Straits Environmental Profile.
- GEF/UNDP/IMO Regional Programme for the Prevention and Management of Marine Pollution in the East Asian Seas.
- CRMP, 1998. Laporan Penyelidikan Geologi Daerah Pesisir Pantai Propinsi Lampung. Technical Report CRMP Lampung.
- Giesen, W., 1991. Tulang Bawang Swamps, Lampung. PHPA/AWB Sumatra Wetland Project Report No 15, AWB/PHPA Bogor, 42 pp.
- Giesen, W., 1993. Indonesian mangroves; an update on remaining area and main management issues. Presented at International Seminar on "Coastal Zone Management of Small Island Ecosystems, Ambon 7-10 April 1993.
- Giesen, W. and Sukotjo, 1991. The Wetlands of Kerinci Seblat National Park, Jambi, Sumatra.
- Hapsoro, 1995. Studi Beberapa Karakteristik Habitat Itik Serati (*Cairina scutulata* Muller, 1840) di Taman Nasional Way Kambas. Fak. Kehutanan, IPB.
- HIMBIO, 1995. Beberapa Aspek Ekologi Mentok Rimba di Taman Nasional Way Kambas Propinsi Lampung, Indonesia. Himpunan Mahasiswa Biologi, Universitas Padjadjaran
- Ismono Hadi, Nanang Trenggono, and Benyamin, 1996. Aspek Sosial Ekonomi pada Pengusaha Ikan Asin di Pulau Pasaran Teluk Betung Barat, Bandar Lampung. Fakultas ISP, UNILA.
- Jepson, P., and R. Ounsted (ed.), 1997. Birding Indonesia. A Bird-watcher's Guide to the World's Largest Archipelago. Periplus Editions/Birdlife International.

- Karden Eddy Sontang Manik, 1991. Analisis Daya Dukung Lingkungan di Bagian Hulu Daerah Aliran Sungai Way Seputih Lampung Tengah. Fakultas Pertanian, UNILA, Lampung
- Karden Eddy Sontang Manik, 1995. Penetapan Baku Mutu Limbah Cair Berdasarkan Daya Dukung Badan Air Sungai. Paper presented at the Seminar on "Penetapan Baku Mutu Limbah Cair Daerah, 28 March 1995. BLH Pemerintah Daerah Tingkat I Lampung.
- Kartawinata, Kuswata, 1983. The Development of Vegetation on Krakatau Islands. In: Proceedings of Workshop on Coastal Resources Management of Krakatau and The Sunda Strait Region, Indonesia, Jakarta, August 19 - September 6, 1981.
- PU, 1996. Publikasi Data Debit Sungai Tahunan di Propinsi Lampung 1996. Proyek Pengelolaan Sumber Air dan Pengendalian Banjir, Lampung.
- PHPA/AWB Sumatra Wetland Project. Interim Publication No 12. Asian Wetland Burau, Bogor, Indonesia.
- RePPPProT, 1988. Review of Phase I Results Sumatra. Regional Physical Planning Programme for Transmigration. Department of Transmigration/ODA. Volume II Annexes.
- Rusila Noor, Y., Giesen, W., Enis Widjanarti H. and M.J. Silvius, 1994. Reconnaissance Survey of the Western Tulang Bawang Swamps, Lampung Sumatra. PHPA/AWB-Indonesia, Bogor.
- Soejani, M., 1976. Hasil Penelitian Masalah dan Pengendalian Tumbuhan Pengganggu Air Rawa Pening. Laporan Akhir. SEAMEO-BIOTROP.
- Suharsono, 1998. Condition of Coral Reef Resources in Indonesia. Jurnal Pesisir & Lautan, Vol. 1, No. 2, 1998.
- Thomascik, T., A.J. Mah, A. Nontji and M. Kasim Moosa, 1997. The ecology of the Indonesian Seas. Part I and II. Periplus Editions.
- UNILA, 1991a. Pemakaian Bahan Kimia untuk Pertanian di Propinsi Lampung. UNILA/BAPPEDA TK I Lampung/ Euroconsult.
- UNILA, 1991b. Pencemaran Oleh Industri di Propinsi Lampung. UNILA/BAPPEDA Tk I Lampung/ Euroconsult.
- Utomo, M., Sugeng P. Harianto dan Thoha Bs. Jaya, 1991. Kondisi Rona Lingkungan Way Tulang Bawang. PSL UNILA/Pemda Tk I Lampung.
- Watson, D., D. Setiapermana, G. Vigers, 1993. Marine Environmental Quality: Perspectives on ASEAN Criteria and Monitoring. Asean - Canada Cooperative Program on Marine Science.
- Whitten, A.J., S.J. Damanik, J. Anwar and N. Hisyam, 1997. The Ecology of Sumatra. Gadjja Mada University Press.
- Zainal Abidin, M. Irfan Affandi and Anton A. Gumilar, 1998. Analisis Ekonomi Program Penanaman Hutan Bakau Model Silvofishery dan Hutan Kemasyarakatan di Pantai Timur Propinsi Lampung.
- Zieren, M., O tong Suhara and D idin Krisnabudhi, 1997. Profil Lingkungan W ilayah Pesisir Propinsi Riau, Indonesia. UNDP /BANGDA /BAPEDA TK I Riau/PT Ardes Perdana.

Annexes

Annex II: Hard Coral species of Krakatau Island

Family/Species		Family/Species		Family/Species	
Astrocoeniidae		<i>Fungia (Fungia) Fungites</i>	.	<i>Oulophyllia crispa</i>	.
<i>Stylocoeniella spp.</i>	.	<i>Fungia (Pleuraetis) scutaris</i>	.	<i>Plesiastrea sp</i>	.
Thamnasteriidae		<i>Fungia (P.) paumotensis</i>	.	<i>Plesiastrea versivora</i>	.
<i>Psammocora contigua</i>	.	<i>Heliofungia actiniformis</i>	.	<i>Cyphastrea spp</i>	.
<i>Psammocora digitata</i>	.	<i>Ctenactis crassa</i>	.	<i>Leptastrea spp</i>	.
<i>Psammocora explanula</i>	.	<i>Herpolitha limax</i>	.	<i>Echinopora lamellosa</i>	.
Pocilloporidae		<i>Polyphyllia talpina</i>	.	<i>Trachyphyllia geoffroyi</i>	.
<i>Pocilloporidae damicornis</i>	.	<i>Halomitra pileus</i>	.	Oculinidae	
<i>Pocilloporidae eydouxi</i>	.	<i>Sandolthia robusta</i>	.	<i>Galaxea spp</i>	.
<i>Pocilloporidae verrucosa</i>	.	<i>Lithophyllon undulatum</i>	.	Merulinidae	
<i>Pocilloporidae woodjonesi</i>	.	<i>Podabacia crustacea</i>	.	<i>Merulina ampliata</i>	.
<i>Stylophora pistillata</i>	.	Poritidae		<i>Paraclavaria triangularis</i>	.
<i>Seriatopora callendrum</i>	.	<i>Alveopora sp.</i>	.	Mussidae	
<i>Seriatopora hystrix</i>	.	<i>Goniopora sp.</i>	.	<i>Achanthastrea bowerbanki</i>	.
Acroporidae		<i>Porites lobata</i>	.	<i>Lobophyllia hemprichii</i>	.
<i>Astreopora spp.</i>	.	<i>Porites lutea</i>	.	<i>Lobophyllia corymbosa</i>	.
<i>Montipora spp.</i>	.	<i>Porites spp.</i>	.	<i>Symphyllia spp</i>	.
<i>Montipora foliosa</i>	.	<i>Porites spp.</i>	.	<i>Symphyllia radians</i>	.
<i>Montipora angulata</i>	.	<i>Porites andrewsi</i>	.	<i>Scolymia vitiensis</i>	.
<i>Montipora explanata</i>	.	Faviidae		<i>Cynarina lacrymalis</i>	.
<i>Acropora hyacinthus</i>	.	<i>Caulastrea sp.</i>	.	Pectinidae	
<i>Acropora robusta</i>	.	<i>Favia amicornum</i>	.	<i>Pectinia lactuca</i>	.
<i>Acropora secale</i>	.	<i>Favia fava</i>	.	<i>Pectinia paeonia</i>	.
<i>Acropora yongei</i>	.	<i>Favia laxa</i>	.	<i>Mycodium elephantotus</i>	.
<i>Acropora spp.</i>	.	<i>Favia mathaii</i>	.	<i>Echinophyllia spp</i>	.
Agariciidae		<i>Favia maxima</i>	.	<i>Echinophyllia aspera</i>	.
<i>Pavona cactus</i>	.	<i>Favia pallida</i>	.	<i>Echinophyllia echinata</i>	.
<i>Pavona explanulata</i>	.	<i>Favia spp.</i>	.	<i>Echinophyllia orpheensis</i>	.
<i>Pavona maldivensis</i>	.	<i>Favites abdita</i>	.	<i>Oxypora lacera</i>	.
<i>Pavona varians</i>	.	<i>Favites spp.</i>	.	Caryophylliidae	
<i>Pavona venosa</i>	.	<i>Goniastrea retiformis</i>	.	<i>Euphyllia glabrescens</i>	.
<i>Leptoseris explanata</i>	.	<i>Goniastrea edwardsi</i>	.	<i>Euphyllia ancora</i>	.
<i>Leptoseris mycetoseriodes</i>	.	<i>Goniastrea spp.</i>	.	<i>Euphyllia divisa</i>	.
<i>Leptoseris scabra</i>	.	<i>Goniastrea benhami</i>	.	<i>Physogyra liechtensteini</i>	.
<i>Gardinoseris planulata</i>	.	<i>Platygyra spp.</i>	.	<i>Plerogyra sinuosa</i>	.
<i>Pachyseris sp.</i>	.	<i>Leptoria phrygia</i>	.	Dendrophyllitidae	
Siderastreidae		<i>Oulophyllia crispa</i>	.	<i>Turbinaria peltata</i>	.
<i>Coscinaraea sp.</i>	.	<i>Hydnophora exesa</i>	.	<i>Tubastraea aurea</i>	.
<i>Coscinaraea wellsii</i>	.	<i>Hydnophora microconos</i>	.	<i>Tubastraea diaphana</i>	.
Fungiidae		<i>Hydnophora rigida</i>	.	<i>Dendrophyllia sp</i>	.
<i>Fungia (Cycloseris) spp.</i>	.	<i>Oulastrea crispata</i>	.	Helioporidae	
<i>Fungia (Verrillofungia) sp.</i>	.	<i>Diploastrea sp.</i>	.	<i>Heliopora coerulea</i>	.
<i>Fungia (Danajungia) scruposa</i>	.	<i>Montastrea valenciennesi</i>	.		

Source: (Salm et al. 1981); (Sukarno and Suharsono 1983) in Tomascik, et al. 1997