*“Reversing Environmental Degradation Trends in the South China Sea and Gulf of Thailand”*

# MANGROVES IN THE SOUTH CHINA SEA

**UNEP/GEF**
**Regional Working Group on Mangroves**

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**Cover Photo:** Mangroves in Xhan Thuy, Ramsar site, Viet Nam - Professor Nguyen Hoang Tri.

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**FOREWORD**

The characteristic vegetation of tropical shorelines is mangrove, a habitat, which has been under-valued in the past and consequently has been subject to extensive removal and degradation in the Southeast Asian Region.

The extensive conversion of mangrove in the countries bordering the South China Sea during the sixties and seventies often reflected short term economic opportunities that benefited a few individuals and neglected the longer term and more widely felt, but poorly understood benefits derived from mangrove services such as coastal protection.

Awareness of the importance of mangroves in Southeast Asia was increased during the 1980s by the UNESCO supported COMAR programme that mobilised and enhanced national capacity to undertake scientific studies of the mangrove habitat. This programme significantly increased not only our scientific understanding of this important habitat but also increased both public and decision makers awareness of the goods and services provided by mangrove vegetation and the animals that depend upon them.

One outcome of this UNESCO Programme was the formation of the International Society for Mangrove Ecosystems (ISME), which supports and promotes international networking and activities designed to promote the study and understanding of mangrove systems.

The UNEP/GEF project "Reversing Environmental Degradation of the South China Sea and Gulf of Thailand builds upon this foundation of regional capacity in attempting to address the continuing trends of degradation of mangrove systems. This project builds not only on the existing knowledge base but also on the human capacity in the countries of the region. Most of the members of the Regional Working Group on mangroves received training and experience through this UNESCO Programme.

The support of the United Nations Environment Programme and the Global Environment Facility to this project is timely. Even with an increased understanding of the importance of mangrove goods and services we have been unable to reverse the trend of loss and degradation at a regional scale. Although the rate of loss has declined in some countries around the South China Sea it remains alarmingly high given the global significance of this region for the diversity of plants and animals that mangroves support.

The UNEP/GEF South China Sea Project is unique, firstly in being the first programme to which all the countries bordering the South China Sea have agreed to implement co-operatively. Secondly this project it places a strong emphasis on practical and pragmatic ways to address the root causes of priority problems in the coastal zones.

Emeritus Professor Sanit Aksornkoae

One such cause is our inability to value adequately in economic terms the goods and services provided by mangroves. Since we cannot place a dollar value on the resources we are unable to provide adequate economic arguments to convince planners and developers that the longer term economic benefits of sustainably using our mangrove systems outweigh the short term economic benefit of their removal. The challenge for this project is to address this scientific and information failure.

I am pleased to have been asked to write the foreword to this booklet which represents the first collective output from the Regional Working Group on Mangroves, and which has been compiled as background to next phase of project implementation when demonstration activities will be undertaken. As such it puts into a wider, global perspective the importance of the mangroves of this region and hence the need for concrete action. Determining the priority that individual national actions have from a regional perspective has been a significant task for the Regional Working Group on mangroves and one, which has served to strengthen collaboration between the focal points from each country. I look forward to seeing the outcomes of this initial collaboration.

Sanit Aksornkoae

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## INTRODUCTION

**Global distribution.** Mangroves occupy the humid tropical belt 30° North and South of the equator, with extensions beyond these latitudes in certain areas (Spalding *et al*., 1997). Two main centres of diversity have been identified. The eastern area is centred on the Indo-Pacific with its eastern limits in the central Pacific, and the western limits, along the eastern seaboard of Africa. The western centre includes mangroves found along the African and American coasts of the Atlantic Ocean, the Caribbean Sea and Gulf of Mexico, and the Pacific coastal areas of the Americas. The eastern group has about five times the species diversity recorded in the western region.

Recent estimates (FAO, 2003) suggest that Asia supports around 39% of the world's total of 14.6 million hectares of mangrove, down from 42% a decade ago. The bulk of this, 28% of the world's remaining mangroves, are found in the seven countries participating in this project.

**Biological Diversity.** Some 41 genera of true mangrove species are found in the Indo-west Pacific compared with only 5 genera in the Atlantic and Pacific seaboard of the Americas. The most diverse mangrove stands occur in Southeast Asia with up to 42 species occurring in a single location. The diversity of plant species, is reflected in the diversity of the animals, both aquatic and terrestrial that are resident in these communities. In addition to the resident plants and animals, mangrove habitats are important staging posts for migratory species including many shore birds that move seasonally from the northern to the southern hemispheres.

**Loss of Mangrove, world-wide.** FAO estimates that a quarter of the world's mangrove has been lost over the last twenty years although the rate of loss during the 1990's (1 percent per annum) is down from the 1980's rate of 2 percent per annum. This reflects the fact that many countries have now banned the conversion of mangrove for aquaculture, and require environmental impact assessments prior to large-scale conversion of mangrove lands.

The total area of mangrove lost in the seven participating countries over different time spans (70 years for the Philippines) was estimated in 1998 at 4.2 million ha suggesting that over half of the original mangrove had been lost during the last century. It should be noted that, estimates of both original and present mangrove area vary greatly in the literature, reflecting differences in definition and modes of assessment. The figures in Table 1 are considered by FAO as the most reliable estimates, while the estimates for 2000 are considered indicative only, given the length of time that has elapsed since the last reliable assessment.

The causes of mangrove destruction along the coastlines bordering the South China Sea, include conversion to pond aquaculture, particularly of shrimp, clear felling of timber for woodchip and pulp production, land clearance for urban and port development and human settlements, and harvest of timber products for domestic use. The national impact of each economic activity is difficult to quantify, nonetheless, shrimp culture would seem to be the most pervasive economic imperative for mangrove conversion.

**Reversing Environmental Degradation in the South China Sea and Gulf of Thailand.**

**Cambodia, China, Indonesia, Malaysia, Philippines, Thailand, Viet Nam**

In 1996, the countries bordering the South China Sea requested assistance from UNEP and the GEF in addressing the issues and problems facing them in the sustainable management of their shared marine environment. From 1996 to 1998 initial country reports were prepared that formed the basis for the development of a Transboundary Diagnostic Analysis, which identified the major water related environmental issues and problems of the South China Sea. Of the wide range of issues identified the loss and degradation of coastal habitats, including mangrove, coral reefs, seagrass and coastal wetlands were seen as the most immediate problem. Over-exploitation of fisheries resources and land-based sources of pollution were also considered significant issues requiring action.

In 1999 the governments, through the Co-ordinating Body for the Seas of East Asia endorsed a framework Strategic Action Programme that established targets and timeframes for action. In December 2000, the GEF Council approved this project with UNEP as the sole Implementing Agency operating through the Environmental Ministries in the seven participating countries and with over forty specialised Executing Agencies at national level directly engaged in the project activities.

Table 1 Estimates of area (Ha) and rates of loss of mangrove habitat in seven countries bordering the South China Sea, compared with the world totals. [Data from FAO, 2003]

| | Estimates of mangrove area in Ha | | | | | Rates of loss | |
|---|---|---|---|---|---|---|---|
| | Most recent | Date | 1980 | 1990 | 2000 | 1980 - 1990 | 1990-2000 |
| **Cambodia** | 72,835 | 1997 | 83,000 | 74,600 | 63,700 | -1.1 | -1.6 |
| **China** | 36,882 | 1994 | 65,900 | 44,800 | 23,700 | -3.8 | -6.2 |
| **Indonesia** | 3,493,110 | 1988 | 4,254,000 | 3,530,700 | 2,930,000 | -1.8 | -1.8 |
| **Malaysia** | 587,269 | 1995 | 669,000 | 620,500 | 572,100 | -0.7 | -0.8 |
| **Philippines** | 127,610 | 1990 | 206,500 | 123,400 | 109,700 | -5 | -1.2 |
| **Thailand** | 244,085 | 2000 | 285,500 | 262,000 | 244,000 | -0.9 | -0.7 |
| **Viet Nam** | 252,500 | 1983 | 227,000 | 165,000 | 104,000 | -3.1 | -4.5 |
| **Total** | 4,814,291 | | 5,790,900 | 4,821,000 | 4,047,200 | average -1.8 | average -1.7 |
| **World** | 15,763,000 | 1992 | 19,809,000 | 16,361,000 | 14,653,000 | -1.9 | -1.1 |
| **% world total** | 30.5 | | 29.2 | 29.5 | 27.6 | | |

**Shrimp farming.** A recent centre-page spread in the Jakarta Post described the world's largest shrimp farm of 80,000 ha constructed on land re-claimed from mangrove at Bumi Dipasena. Integrated into the farm was a shrimp feed mill producing 220 tonnes of feed per year and a hatchery producing 8 billion fry/year on a 220 ha site. Production of shrimp was estimated at 50,000 tonnes/year and 200 tonnes/day could be stored in a cold storage facility. Infrastructure included a 160 megawatt power plant, waste water treatment plant, a port, a housing estate for 110,000 people and 2,500 Km of canals.

Unlike such large-scale production the major cause of mangrove loss is conversion to small-scale extensive shrimp ponds. Systems that are unsustainable in the longer term since problems of water quality and disease, result in many extensive low technology, shrimp cultivation ponds being abandoned after three to four years of operation. They become unproductive without capital and technical investment in maintaining water quality.

**Transboundary issues.** From a global perspective the major transboundary issues surrounding the loss of mangrove habitats include the loss of unique biological diversity that cannot be replaced, and the loss of mangrove services. Many off-shore fisheries resources such as shrimp and demersal fish breed in mangrove areas and are fished off-shore by more than one nation's fishing fleet.

From a regional perspective the loss of off-shore fisheries production, both shrimp and demersal fish may have transboundary implications since the off-shore fishing fleets may not come from the country in which the mangrove habitats occurs. Thus cutting mangroves in one country may impact the fishing community in a neighbouring country.

It has been known for many decades that the off-shore shrimp catch is directly proportional to the area of in-shore mangroves since these provide the habitats within which the juvenile penaeid shrimp feed and mature, before moving off-shore in later phases of their life-cycle.

A different form of transboundary influence is seen through the operation of the world markets and global trade in shrimp. The high level of demand for shrimp in Japan, North America and Europe sets the world price such that, economic incentives for conversion of "non-productive" mangrove habitats operate at both the individual and national levels in producing countries. Hard currency income and economic development fuel the motives at the national level whilst individual producers, at least in the short-term derive considerable cash income from cutting their mangrove and converting to shrimp ponds. It is recognised in countries such as Thailand that these short-term benefits result in longer-term costs that have often to be met from public funds.

On a smaller scale trade in charcoal derived from mangrove in Cambodia to Thailand was a major cause of mangrove loss in the recent past, in the areas of Cambodia close to the Thai border.

**Loss of biodiversity**. Whilst the inventory of the flora and fauna associated with mangrove areas in the South China Sea region is far from complete, it is nevertheless obvious that loss of these important habitats has resulted in loss and/or decline in associated species many of which are now considered endangered or threatened. Endangered species found in mangrove in the region include the proboscis monkey, *Nasalia larvatus*, which eats young shoots and growing tips of *Sonneratia* and *Avicennia* trees, the crocodile *Crocodilus porosus* and swamp birds including *Ardea* and *Egretta* (Low et al., 1994).

Around 30% of the world's remaining mangrove, occurs in this region but the annual rate of loss is 55% greater than the world average. Such losses represent a loss of global biological diversity that must be a matter of global concern.

## MANGROVE DISTRIBUTION AND DIVERSITY IN THE SOUTH CHINA SEA

**Geographic and abiotic limits to mangrove habitats.** Mangroves are restricted in their world-wide distribution by the 24$^0$C seawater isotherm (Hutchings & Saenger, 1987), thus they form one of the dominant habitats along tropical and sub-tropical coastlines such as those bordering the South China Sea. Mangroves occur on coasts with low wave energy, where land-based sediments carried by rivers, or off-shore marine sediments are deposited in the inter-tidal and sub-tidal zones.

Unlike coral reefs, mangroves are found in areas with a wide range of salinities from 0 to 35 psu. Individual trees may be subjected to varying salinity regimes depending upon the state of the tide and the inputs of freshwater from the landward catchments. Different mangrove species tolerate different levels of salinity with species such as *Sonneratia ovata* preferring the inland more freshwater environments and *S. caseolaris* and *Avicennia marina* capable of withstanding high salinity and wave action on the seaward fringe. *Avicennia* spp. are also found towards the back of some mangrove stands where high evapouration and low freshwater inputs result in high salinity soils. In many areas, a distinct zonation in the distribution of plant species can be seen, reflecting the diurnal patterns of tidal inundation.

**Ecology of mangroves.** Mangrove trees have special adaptations to enable them to live under conditions where the substrate is soft and wave action threatens to dislodge them. *Rhizophora* species have stilt roots for support, whilst *Avicennia* and *Sonneratia* have cable roots.

Prop roots of *Rhizophora* sp.

Adaptations to living in a saline environment include partial exclusion of salt at the root level (as in *Rhizophora*) or the presence of salt extruding glands on the leaves (as in *Acanthus*). Not only is salinity high, but oxygen is low in the soils in which mangroves grow. Just a centimetre or so below the surface of the substrate, the mud is black and oxygen levels are low. Bacteria that use sulphur to produce energy thrive in this environment and when stirred the mud may produce a strong smell of hydrogen sulphide.

Animals burrowing in mangrove soils must ventilate their burrows and do so through rythmic movements of their bodies, producing currents that draw oxygen rich water below the surface. Mangrove trees such as *Avicennia* and *Sonneratia* spp. have pneumatophores, or breathing roots, that stick up through the surface of the mud, whilst the roots of *Bruguiera* spp. have "knees" above the surface for respiration. These breathing roots have lenticels, which are also found on the bark of *Bruguiera* and through which oxygen passes into the plant.

Pneumatophores of *Sonneratia sp*., Thailand

**Vivipary.** Young seedlings of any plant require lots of freshwater during their early stages of growth and the saline environment in which mangroves occur is not suitable for young seedlings. To overcome this problem, species of mangrove trees including those in the family Rhizophoraceae are viviparous. The seeds germinate while still attached to the parent plant. The long radicle, which enables the propagule to penetrate and establish itself in the soft substrate, also serves as a food store once the young plant becomes separated from its parent.

Propagules of *Rhizophora mucronata*

**Mangrove species and community structure.** The diversity of tree species in the mangroves of the South China Sea is the highest in the world. More that 30 species of true mangroves are known to occur in single locations and some 46 species are recorded from the region as a whole. Of these *Brownlowia tersa* and *Bruguiera hainesii* are listed in the IUCN plant red data book, as being endangered. Table 2 shows the occurrence of true mangroves in seven countries bordering the South China Sea.

Animal diversity is also high, the average number of species of macro-crustaceans recorded from 26 sites was 27, with 67 species being found in Fangchenggang, China. The number of fish species reaches 103 in Can Gio, Vietnam; and the number of resident birds averages 46 species with 98 species occurring in Trad Province, Thailand. These numbers represent minima since the fauna at most locations has not been fully described.

The vertical structure of mangroves in the SCS is less complex than that of the lowland terrestrial forests in the same area. The number of tree canopy layers is normally one or two, as compared to the 4 or 5 in terrestrial forests. The height and diameter of these trees range from over 30 m and 100 cm respectively in the case of big *Rhizophora apiculata* trees in pristine forests in Indonesia to 2 m and 10 cm respectively for small *Kandelia candel* trees in China. Tree density also varies, ranging from around five to six hundred trees per hectare for mature stands of *Bruguiera* to around 12,000 trees per hectare of rather stunted trees in Fangchenggang, China. Dominant elements of Chinese mangrove forest include the smaller species such as *Avicennia marina* and *Kandelia candel.*

**Productivity, turnover and carbon storage**. Whilst there have been a number of studies on the above-ground biomass and productivity of mangroves, there have been only a few below-ground studies (see Ong et al., 2003).

In terms of sequestering carbon, roots are perhaps the most important plant component. The annual increment of root biomass is 0.42 t C $ha^{-1}$ in a 20 year-old stand of *Rhizophora apiculata,* for example (Ong *et al.*,1995) which is comparable to the 0.52 t C $ha^{-1}$ annual increment of canopy biomass. Annual turnover of small litter (flowers, fruits leaves, twigs, and small branches,) accounts for 5.1 t C $ha^{-1}$.

Although, the annual turnover of *Rhizophora apiculata* roots is not available, Ong *et al.* (1995) argued that this might be at least in the same order as that for leaf turnover. Since this turnover occurs below ground, more of this component will be buried than the above-ground small litter (much of which is exported with the tides or consumed by detritivorous crabs). A significant amount of root organic matter is leached from roots but the proportion that is sequestered in soil is not known.

Table 2 “True” mangrove species recorded from the countries bordering the South China Sea.

| | Cambodia | China | Indonesia | Malaysia | Philippines | Thailand | Vietnam |
|---|---|---|---|---|---|---|---|
| *Acanthus ebracteatus* | X | X | X | X | | X | X |
| *Acanthus ilicifolius* | X | X | X | X | | X | X |
| *Acanthus xiamenensis* | | X | | | | | |
| *Acrostichum aureum* | X | X | X | X | X | X | X |
| *Acrostichum Speciosum* | X | X | X | X | X | X | |
| *Aegialitis rotundifolia* | X | | | ? | | | |
| *Aegiceras corniculatum* | X | X | X | X | X | X | X |
| *Aegiceras floridum* | X | | X | ? | X | -- | X |
| *Avicennia alba* | X | | X | X | X | X | X |
| *Avicennia eucalyptifolia* | | | | | X | -- | |
| *Avicennia marina* | X | X | X | X | X | X | X |
| *Avicennia marina var rumphiana* | | | X | | X | -- | |
| *Avicennia officinalis* | X | | X | X | X | X | X |
| *Brownlowia tersa* | X | | | X | | X | |
| *Bruguiera cylindrical* | X | X | X | X | X | X | X |
| *Bruguiera gymnorrhiza* | X | X | X | X | X | X | X |
| *Bruguiera hainesii* | | | | ? | | X | |
| *Bruguiera parviflora* | | | X | X | X | X | |
| *Bruguiera sexangula* | X | X | X | X | X | X | X |
| *Bruguiera sexangula Var Rhyncopetala* | | | X | | | -- | |
| *Camptostemon philippinense* | | | X | | X | -- | |
| *Ceriops decandra* | X | | X | ? | X | X | X |
| *Ceriops tagal* | X | X | X | X | X | X | X |
| *Excoecaria agallocha* | X | X | X | X | X | X | X |
| *Heritiera littoralis* | X | X | X | X | X | X | X |
| *Kandelia candel* | X | X | X | X | | X | X |
| *Lumnitzera littorea* | X | X | X | X | X | X | X |
| *Lumnitzera racemosa* | X | X | X | X | X | X | X |
| *Nypa fruticans* | X | N | X | X | X | X | X |
| *Osbornia octodonta* | | | X | ? | X | -- | |
| *Pemphis acidula* | | X | X | ? | | X | |
| *Peltophorum pterocarpum* | | | | ? | | X | |
| *Phoenix paludosa* | X | | | X | | X | X |
| *Rhizophora apiculata* | X | X | X | X | X | X | X |
| *Rhizophora mucronata* | X | | X | X | X | X | X |
| *Phizophora stylosa* | | X | X | ? | X | -- | X |
| *Scyphiphora hydrophyllacea* | | X | X | X | X | X | X |
| *Sonneratia alba* | X | X | X | X | X | X | X |
| *Sonneratia caseolaris* | X | X | X | X | X | X | X |
| *Sonneratia griffithi* | X | | X | X[1] | | X | |
| *Sonneratia hainanensis* | | X | | | -- | -- | |
| *Sonneratia ovata* | X | X | XX | X | | X | X |
| *Sueda maritime* | | | | ? | | X | |
| *Xylocarpus granatum* | X | X | X | X | X | X | X |
| *Xylocarpus moluccensis* | X | | X | X | X | X | X |
| *Xylocarpus corniculatum* | | | | | | | |

**Limits to mangrove distribution.** The seaward extension of mangroves is limited by inundation, since no mangrove can survive continual or repeated inundation of its crown. The landward extent appears to be limited indirectly by saline influences since outside the zones of saline water penetration the terrestrial halophilic plants are more successful than mangroves. Species such as *Exocoecaria agallocha* are quite capable of growing and surviving in freshwater environments but their rare occurrence in such locations in nature suggests that their landward extent is limited by competition.

**Mangrove zonation.** Since mangroves occur as a fringe of vegetation bordering the boundary between the land and sea it is not surprising that recognizable zones may be distinguished from seaward to landward side. At the seaward margins smaller species such as *Avicennia marina*, and *Sonneratia alba* that can withstand high salinities and inundation by the tide for long periods, predominate. In a typical mangrove stand this seaward fringe is backed by stands of taller *Rhizophera*, which in turn give way to *Bruguiera,* a genus that is less tolerant of inundation than the species of the seaward margin.

Similarly along the sides of estuaries, rivers and creeks draining the mangroves, zones of different species occur with mangroves giving way to terrestrial vegetation inland. In Koh Kong Cambodia, the margins of the estuaries and canals are dominated by *Rhizophora apiculata* and *R. mucronata*. Further inland are found *Avicennia* and *Bruguiera* followed by *Xylocarpus, Ceriops* and *Lumnitzera*. *Nypa fruticans* occurs as extensive stands in the transitional zone between true mangrove and terrestrial forests. The mangrove system is often backed by freshwater swamp forest of *Melalueca* or peat swamp forest, habitats which have been largely destroyed on this region.

**Inundation regimes**. Typical inundation regimes that the dominant mangrove genera of *Bruguiera, Rhizophora, Avicennia and Sonneratia* can withstand are illustrated in Figure 1. Where the frequency of tidal penetration reaches 200 days and 320 tides per year, *Rhizophora* is replaced by, *Bruguiera* as the dominant genus.

The genera *Avicennia* and *Sonneratia* can withstand daily inundation and tidal frequencies of between 700 and 730 per year, but they cannot withstand permanent inundation of their pneumatophores, which must be exposed to the atmosphere for several hours a day if the plants are to survive.

**Hypersaline conditions**. Occasionally in flatter coastal areas where evaporation rates are high and freshwater inputs low, such as Kampot Province Cambodia, the mangroves are backed by, areas of very high salinity, salt flats. The trees in such areas tend to have stunted growth due to physiological stress from infertile saline soils, fine sand accumulation and high evaporation rates due to wind exposure. The scrubby mangrove growth is backed on the landward side by halophilic salt marsh communities.

Mangrove zonation at Teluk Bintuni, Papua, Indonesia

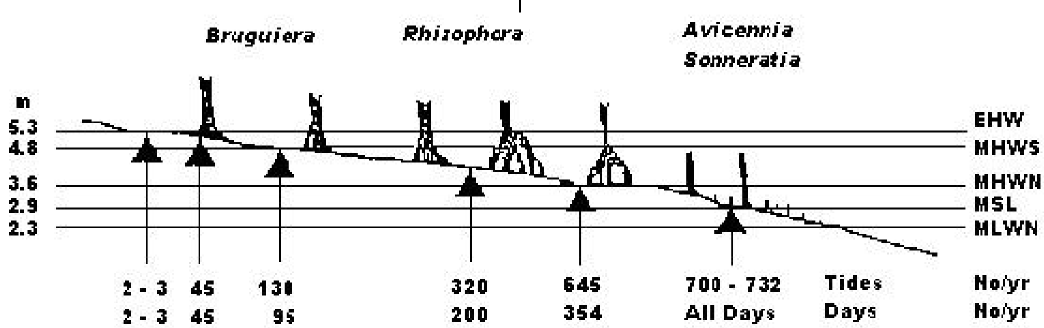



Figure 1 Zonation of dominant mangrove genera in relation to annual inundation patterns at Port Klang, Malaysia. Numbers indicate the number of tides per year and the number of days per year during which the tide reaches each point in the system.

### DIRECT USE OF MANGROVE RESOURCES

**Mangrove trees.** The direct uses of mangrove resources are many and varied including subsistence use by local communities, and commercial, both small and large scale depending upon the extent of the system, and the nature of the resources. The mangrove trees themselves provide construction timber used for house piles, wharfs and jetties, poles for charcoal making and light construction. Trees such as Nypa palm provide fronds used extensively in thatch whilst traditional communities use the spiny mid-rib to construct thorn lined fish traps. Small-scale commercial exploitation of the mangrove trees frequently involves charcoal production producing fuel for household use whilst in contrast, large scale commercial exploitation has involved clear felling trees for wood chips used to produce of rayon.

**Animal and plant resources.** Not only are the trees themselves a valuable resource but the aquatic animals found in mangrove systems are used for food and are again exploited at both a subsistence and a small scale commercial level, often to supply local markets. Frequently the level of exploitation reflects not merely the density of people subsisting directly on the mangroves but also on their proximity to urban centres and the ease with which crustaceans, molluscs and fish can be transported to local markets. The mud crab, *Scylla serrata*, is a familiar item of cuisine throughout the region although pond-culture has now replaced wild caught animals in many areas. The ponds themselves are often constructed in former mangrove areas contributing to degradation of the habitat and loss of natural production.

**Minor uses.** A wide variety of minor uses are found in different locations throughout the region. Mangrove fruits for example particularly those of *Avicennia*, along with sipunculid worms form distinctive elements of local dishes in southern China. In Indonesia, *Nypa* sap is used for alcohol production on both a small and large scale, whilst in the Philippines mangrove bark is used as a source of Tannin for tanning leather. A widespread but small scale resource which has potential for larger scale production is honey from wild bees, living in the mangrove habitat.

Molluscs from mangroves and tidal flats on sale in South Viet Nam

### SERVICES PROVIDED BY MANGROVES

In addition to the direct uses of mangrove trees for timber, charcoal, thatching, and use of animals such as fish, crustaceans, and molluscs for food, mangroves also provide many important environmental services (see Ewel *et al*., 1998).

**Coastal protection**. In areas of high sediment input and low wave action the root structure of the mangrove forest traps sediment resulting in upward accretion of the soil surface, and seaward progression of the mangrove fringe. A well-established mangrove forest system not only provides significant protection to the coastline against erosion from the diurnal tidal cycle but also affords some protection against damage from storm surges. Because of their shallow root system isolated individual mangrove trees do not withstand strong winds, and where significant removal of trees has occurred, the remaining individuals are highly susceptible to wind throw. In a mature mangrove stand the inter-locked root systems of neighbouring trees provide greater support and hence the habitat as a whole provides protection to inland areas against tropical storm winds.

**Carbon sequestration.** Mangroves are also important as they fix a significant amount of carbon, some 10 tonnes per hectare per year, in the plant biomass through net primary production. What is more important is the fact that some 1.5 tonnes of this are sequestered in the mangrove soil for a long period of time (Ong, 1995, 1993). Total root biomass measured in mangroves in Thailand at between 138 and 437 tonnes per hectare is significantly greater than root biomass in temperate mangroves and tropical rainforest. This particular service function may significantly impact the perceived economic value of mangroves in the future if trading in carbon credits under the Kyoto Protocol becomes a reality.

**Biological Diversity Services.** In addition to the intrinsic biological diversity, which mangrove systems support in terms of species restricted to such ecosystems, mangroves also support both migratory and endangered species. Migratory bird species particularly coastal waders and water fowl utilise the mangrove habitats during their seasonal migrations which may extend from the far North through the South China Sea to Australia. Mangroves and associated mud-flats form rich feeding grounds for such species and breeding populations of such migratory species may be dependent upon the continued existence of mangrove habitats, which are used only for a short period annually.

Although the number of endangered species, whose continued existence is dependent upon the mangrove habitat is small there are nevertheless several such species in the mangroves bordering the South China Sea including the estuarine or saltwater crocodile, the proboscis monkey and two species of swamp bird.

**Nursery areas.** MacNae (1974) demonstrated the relationship between mangrove area and yield of penaeid shrimp from off-shore trawling grounds off the East coast of Africa. A general relationship is apparent between the size of the mangrove nursery area and the resultant fishery, suggesting that factors regulating the survival of juveniles in the mangroves are important in determining the size of the adolescent and breeding populations (Robertson, 1988). The physical complexity of the habitat provides juvenile shrimps with refuges from the high predation rates characteristic of more open waters. Penaeid shrimp juveniles feed and grow in the mangroves before migrating off-shore to complete their growth.

Mud crabs, *Scylla serrata* undergo a similar life cycle, the adults undertaking a seaward migration after mating in the mangroves. Berried females can be found off-shore at depths of 7 to 70 metres and the eggs are carried for around 17 days before hatching as larvae that use the ocean currents to return to the estuarine environment.

There is no doubt whatsoever that mangroves are very important nursery grounds for off-shore commercial prawn and demersal fish species. The mangrove national park at Ca Mau in Viet Nam has been specifically established as a reserve to enhance and maintain the productivity of off-shore fisheries.

In addition, since the 1970s, mangroves have been viewed as providing important sources of food to coastal fisheries. Recent studies (e.g. Loneragan *et al*., 1997 and Chong *et al*., 2001) using stable isotopes suggest that this role may in fact be restricted to areas within the mangrove estuary and a few kilometers off-shore.

**Coastal water quality**. Mangroves also contribute significantly to maintaining the quality of the nearby coastal waters. They act as a "sink" not only for sediments, but also for nutrients like nitrogen and phosphorus, and contaminants such as heavy metals (e,g, Tam & Wong, 1995) which are carried seawards from sources in the inland areas. Quantifying the economic value of such services is difficult, frequently resulting in an under-valuation of the total economic benefits derived from mangrove services. In some areas bordering the South China Sea the capacity of natural mangrove systems to absorb additional nutrient inputs from human and agricultural wastes is being tested, and could potentially increase the total economic value of such systems.

Without a mangrove fringe to act as a filter contaminants and pollutants pass directly to the coastal waters impacting natural fish production and aquaculture. The impact of loss of mangroves on pearl production in Guangxi Province China illustrates the importance of this mangrove service (see box below).

Oyster culture in front of mangroves, Fanchenggang, China

WATER QUALITY AND PEARL FARMING IN SOUTHERN CHINA

Historically, mangrove thrived along the coastline of Hepu, Guangxi, China, where pearl culture (*Pinctada martensi*) has been practiced for nearly 2000 years, mainly in seven areas in the proximity of mangroves, referred to locally as "pearl pools". By 1995 up to 70% of the mangroves were removed due to coastal reclamation, and production of good quality pearls declined, suggesting a close link between pearl growth and mangroves. In Bailong Town of Hepu County, for example, 333 ha of mangroves had been destroyed by 1974.

Before 1974, production was at a level of 1.25 kg of pearls per 10,000 shells, which had dropped to 0175 kg/10,000 shells by 1999. Over the same period pearl quality declined and the price also declined to such a low level (5,000 Yuan/kg) that this once profitable industry was nearly destroyed. Most of the pearl farmers in Bailong, who had been engaged in pearl production for many generations, had to choose an alternative job or move to Zhenzhu Bay in Fangchenggang City of Guangxi to continue their traditional pearl farming. In 1999, there were still 1030 ha of mangroves in Zhenzhu Bay where pearl farming is extensively practiced. In 1999 in Zhenzhu Bay, pearl production rate was on average 1.0kg/10,000 shells, and pearl price was 12,000 Yuan/kg. This suggests that profit from pearl farming in mangrove areas was 13.7 times higher than in areas where no mangrove grows.

#### VALUING MANGROVE GOODS AND SERVICES

Our current inability to value, in economic terms, the goods and services provided by mangroves stems in part from a lack of agreement concerning the techniques by which value should be determined and in part the lack of comparability between values across spatial boundaries.

The total economic value of a natural system reflects both use and non-use values and whilst it is possible to value many direct and indirect uses through market pricing the resulting total value does not reflect the non-use values. Non-use values, such as the value of an endangered species, or the aesthetic value of a landscape are difficult to determine in a manner that allows comparison of the results across different social and economic boundaries.

Even the value for direct uses such as the market value of mud crabs collected from mangrove areas is highly variable across the region being determined by the proximity of the area to markets and the local economic conditions. Values, where they have been determined are therefore highly specific, relating to a particular area of mangrove at a specific point in time.

#### CONSEQUENCES OF LOSING MANGROVE HABITATS

When mangrove forests are destroyed and replaced by alternative land use not only are the species of plants and animals lost but the many services provided by mangrove systems are lost as well. Since the valuation of such service functions is difficult, total economic values of mangroves are rarely considered in the development decision-making process.

When mangroves are destroyed for shrimp farms and other purposes, the decisions are often based on a consideration of the direct economic returns from shrimp farming without consideration of the total economic value of direct and indirect uses of mangrove goods and the value of services that are renewable and sustainable. Mangrove degradation causes losses in direct and indirect economic values that support socio-economic development at both local and national scales.

Once lost, the productivity of the mangroves that contributes to wild shrimp and fish production is lost and whole coastal communities may loose their means of livelihood. In Viet Nam recognition of the value of mangrove for coastal protection from storm surges has led to changes in government policy that result in the protection and non-use of seaward mangrove fringes which are seen as protective barriers for the economic activities taking place immediately inland.

#### MANGROVE DEMONSTRATION SITES

**Goal and Purpose.** The primary goal of the demonstration sites is to "test" and "demonstrate" actions, which either "reverse" environmental degradation or will demonstrate methods of reducing degradation trends if adopted and applied at a wider scale. In the context of mangrove ecosystems, environmental degradation results largely from the total or partial conversion of natural habitats to alternative uses, or negative impacts on the biological community structure, productivity or species diversity of the habitats, through non-sustainable patterns of resource extraction (over-exploitation). The demonstration sites therefore focus on sustaining biological diversity at the species and habitat levels rather than on the population or genetic level of biodiversity.

More specifically, demonstration sites are directed to objectives such as: **maintaining** existing biodiversity; **restoring** degraded biodiversity; attempting to **remove or reduce the cause**, of degradation; or attempting **preventive actions** that prevent adoption of unsustainable patterns of use.

**Maintaining existing biological diversity.** Within the region there exist many parks and protected areas, which with varying degrees of success, are attempting to maintain the biodiversity that exists within the park or protected area. Such actions do not address the trend in degradation since they effectively establish "refuges" or enclaves of biodiversity with no, or reduced use. Such management regimes can be replicated only by extending the total area under this type of management, and there are severe limitations to such an expansion, in all countries, which reflect land and sea tenure, and current use regimes.

**Restoring degraded systems**. There are areas in almost all countries of the region where activities involving re-planting and re-forestation, of degraded mangrove are undertaken. Again this type of potential demonstration activity does not really address the primary objective of the project in that such actions can only be under-taken once the degradation has occurred.

Replanted mangrove, Trad Province, Thailand.

**Changing patterns of use.** There are, few activities in the region designed to attempt to reduce the rate of degradation through halting or changing patterns of unsustainable use, yet it is these forms of action, which if successful, and if replicated, will reverse the regional trends in environmental degradation. The value of such demonstration sites appears obvious, such actions if successful, can be replicated and adopted in areas, which are not under conservation or protection regimes. Sinc e "use" rather than "non-use" is the norm for coastal habitats in this region the potential opportunities for actions of this type are correspondingly greater.

**Reducing the causes of degradation.** As noted in the Transboundary Diagnostic Analysis the major cause of mangrove loss and degradation in the region is their conversion to shrimp culture. Where conversion to extensive shrimps ponds is continuing, actions that result in improved efficiency of pond culture for longer periods of time, whilst at the same time generating the same level of income, would reduce the trend of continuing loss of habitat. Identification of alternative livelihoods that generate comparable income but have a lower impact on the state of the habitat, and demonstration of their utility, transferability, and replicability, would ideally serve the goal and objectives of the project.

**Preventing future degradation.** Actions that halt the adoption of unsustainable patterns of use before they commence are perhaps, the most difficult demonstration projects to design, since they involve not only identifying and demonstrating the alternatives, but also identifying specific areas where the threats are most imminent and at the same time can be potentially altered in advance. For example one might identify in a national forestry plan a planned development of large-scale commercial timber exploitation, which could be implemented using a more sustainable approach. In the case of commercial timber extraction from mangrove systems, rather than clear felling the entire area, adoption of a rotational pattern of extraction, might result in lower economic returns in the short term, but sustainable economic returns over the longer term.

**What is being demonstrated?** The term "demonstration site", can be interpreted by different individuals, to mean quite different things. In the context of this project one needs to examine not only the goals and purpose for the sites, but also: "what" is being demonstrated; to "whom" is it being demonstrated; and, "how" is it being demonstrated. In considering **"what"** is to be demonstrated one can identify at least three types of potential demonstration site, namely; function related sites; process related sites; and problem related sites.

**Function related sites.** Existing sites that demonstrate sustainable use of mangroves for timber production, such as the Matang Mangroves in Malaysia, with over 100 years of sustainable forestry use of the area; or demonstrate use for eco-tourism such as Can Gio in Viet Nam; or for environmental services such as Pak Phanang Bay in Thailand are all examples of this type of site. Such sites must have demonstrated successful sustainable use, for a specific purpose, preferably over a long period. Demonstration potential is higher for sites where th e techniques used are not widespread throughout the region. It is likely that external grant funding requirements for many such sites would be small.

**Process related sites.** Again such sites might include existing sites that demonstrate innovative management processes that are not widespread in the region. Some examples might include: community based, local interventions for sustainable use; transboundary sites demonstrating cross-border collaboration in management of single ecosystems; management of habitats by one country with benefits to a second; public private partnerships; and, application of new modes of organisation and/or management, such as the current decentralisation of responsibilities to Provincial and local government in Indonesia).

Community managed mangroves, Trad Province, Thailand

Such sites would be chosen on the basis that they have, demonstrated already, or potentially could demonstrate in future, new and innovative modes of managing the resources and the env ironment. This region is particularly rich in examples of community-based and local government management of coastal areas some of which have proven successful in the longer term, and some of which are less successful. Some successful examples of community-based management have been identified as models for use as demonstration sites within the region.

**Problem related sites.** Sites could be chosen to demonstrate innovative ways of addressing specific environmental problems such as the management of sewage pollution via non-water treatment methods, using mangrove systems as buffer habitats. Areas in which over-exploitation is occurring could be chosen to demonstrate sustainable extractive use of timber or regulation of fishing gear and fishing pressure. This type of demonstration site could potentially provide models that would be of wider regional and international significance.

**Transboundary management.** At present there is no area of mangrove habitat under collaborative management, involving more than one country, and no identified management regime in one country that can be shown to provide quantifiable benefits to a second. Identification of such sites and their adoption as demonstration sites in the framework of this project provides an innovative demonstration site for the region and could serve as a potential model for other regions. The mangrove demonstration proposal in Trad Province, Thailand is being formulated in collaboration with Cambodian authorities as one such collaborative management regime.

In terms of **the target audiences** and **how the demonstration site is to be operated**, the two questions are clearly related. If one wishes to transfer a model of successful community based management from one area to another, or from one country to another, then the appropriate methods will differ significantly from those that are applicable in terms of transferring techniques and experience at higher organisational levels. Management, at the level of fisheries extension officers, or management at the level of government planners and forestry managers, require quite different mechanisms.

**Regional Co-ordination.** To maximise the potential benefits of the demonstration site interventions a regionally co-ordinated framework of structured visits, study tours and mechanisms for the transfer of experiences and good practices must be implemented at the outset. A co-ordinated programme of exchange visits between demonstration sites is envisaged that will permit individuals from one site to spend extended periods of on-site training at sites in other countries where appropriate solutions to specific problems are being applied. Without such a regionally co-ordinated programme of training and exchange the lessons learned at one site cannot be easily transferred to others and the possibilities of self-funded replication of successful interventions will be reduced.

Considerable experience exists in a number of countries in the region, including Thailand and Indonesia in the establishment of public awareness and extension centres in mangrove areas. Such centres are designed to enhance public awareness of the biology and significance of mangroves and to serve as seedling production and training centres for mangrove reforestation programmes, operated on a community basis.

Mangrove propagules prepared for planting, Trad Province, Thailand

Whilst such centres provide in-country support through training and public awareness few mechanisms exist at a regional level for the transfer of experience between countries. A major role for the Regional Working Group on Mangroves lies in providing such mechanisms. Composed of government nominated, expert national focal points and three regional experts this group represents a considerable pool of expertise available in support of the operation and management of the demonstration sites. Each focal point chairs a national group of institutions with capacity and expertise in all aspects of mangrove research and management. This network will serve as the mechanism for dissemination, in national languages, of the experiences and practices developed during the execution of the demonstration site activities.

Table 3 Rank scores for, and primary purpose of, potential mangrove demonstration site proposals.

| | Total Score | Overall rank | Demonstration purpose |
|---|---|---|---|
| **Cluster 1** | | | |
| **Trad Province** | **162** | **1** | Community based- management for restoration |
| **Welu River Estuary** | **133** | **5** | Reversing degradation |
| **Can Gio** | **120** | **7** | Management for eco-tourism |
| **Pak Phanang Bay** | **115** | **9** | Management for coastline protection |
| **Cluster 2** | | | |
| **Batu Ampar** | **151** | **2** | Management for multiple uses |
| **Busuanga** | **135** | **4** | Multiple management through tenurial instruments |
| **Ca Mau** | **132** | **6** | Management for ecological services |
| **Quinglangang** | **117** | **8** | Protection of endangered species |
| **Bengkalis** | **111** | **10** | Management for charcoal production and restoration |
| **Quezon** | **108** | **12** | Participatory management for aqua-silviculture |
| **Ngurah Rai** | **108** | **12** | Management for training and public awareness |
| **Angke Kaput** | **87** | **14** | Management for environmental education |
| **Cluster 3** | | | |
| **Fangchenggang** | **137** | **3** | Cross-sectoral management |
| **Xuan Thuy** | **109** | **11** | Management for biodiversity conservation |

## DETERMINING REGIONAL PRIORITY OF POTENTIAL DEMONSTRATION SITES

**National and Regional Priority.** Whilst most countries have determined national priorities for intervention including conservation, and sustaining coastal biodiversity, such priorities have generally been determined and agreed independently of one another. The determination of national priority may not necessarily include consideration of the regional and or global significance of a particular site or species. Hence the top priority mangrove site in one country may fall far below the lower priority sites from a second country, when both sets are compared. One major challenge faced by the South China Sea Project was the determination of the comparative significance of different national areas of mangrove habitat that included consideration of transboundary, regional and global factors.

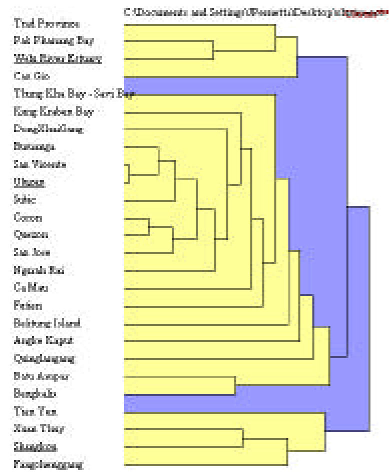
To initiate the process of determining the comparative regional importance of national sites it was agreed by, the Regional Working Group on Mangroves (UNEP, 2002a; 2002b) that a uniform set of environmental data would be assembled for as many sites as possible bordering the South China Sea. Data were initially assembled for forty-four mangrove sites, of which twenty-six data sets were judged by, the Regional Working Group, to be sufficiently well documented, to merit inclusion in a regional comparison (UNEP, in press).

**Similarity between sites.** Recognising that there exist sub-regional differences in the biological diversity contained in mangrove habitats bordering the South China Sea it was agreed that, a statistical comparison of all sites be undertaken in order to determine the relative similarity (and difference) between the sites. These data are presented in Table 3, where it can be seen that a total of seventeen cells (5.4%) lack entries. This data set represents a compromise between a fully comprehensive and descriptive set of parameters and what was available for all sites.

A cluster analysis was performed using the Clustan Graphic6 software programme and the resulting dendrogram is presented in Figure 1. It can be seen that the sites fall into three clusters, two of which are comparatively small (four sites each). These two small clusters encompass sites in China, Thailand and Viet Nam representing the northern and north-western, margins of the South China Sea. The larger central cluster of 18 sites, is more heterogenous, encompassing both insular and mainland sites generally lying in the Southern and Eastern portions of the region.

The purpose of performing such an analysis was to identify groups of similar sites and ultimately to spread the interventions across different groups thus maximising the between site variation covered by the selected interventions.

Figure 1 Cluster diagram of twenty-six mangrove sites bordering the South China Sea based on Euclidean distance and mean proximity.




**Ranking sites.** To arrive at a regional consensus regarding the priorities within each cluster the Regional Working Group initially reviewed the data available for all potential sites and developed a set of environmental criteria and indicators reflecting the biological diversity, transboundary and regional significance of each site. A similar system of criteria and indicators was also developed for the social and economic characteristics of the sites. Both sets of criteria and indicators were reviewed by, the Regional Scientific and Technical Committee (UNEP, 2002c; 2003b) prior to being applied to data from each site, to derive a score representing a regional view of priority. The system has been developed in an open and transparent manner through the process of consensus such that all parties understand and accept the final outcome.

**Priority sites for intervention.** Having agreed the criteria, indicators and scoring system and conducted an independent cluster analysis to group similar sites the rank order within each cluster has been determined and a set of demonstration proposals prepared for consideration by the Regional Scientific and Technical Committee and the Project Steering Committee (UNEP, 2003; UNEP, in press).

It can be seen from Table 3 that proposals have not yet been developed for all top priority sites within each cluster, although it is envisaged that this will be done at a later date. By focussing on sites for which regional priority is high the project aims to meet the double objective of conserving globally significant biological diversity whilst at the same time developing, testing, and refining interventions and management actions that can be applied more widely throughout the region.

Table 4 Selected physical and biological data set for mangrove potential demonstration sites bordering the South China Sea.

| Site | Present Area | Zones spp assoc | % change in area | True mangrove Spp. | Density >1.5m high /Ha | % cover | No. Crustacean. Spp. | No Bivalve | No. Gastropod Spp. | No Fish Spp | No Bird Spp | No migratory bird Spp. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Trad Province | 7,031 | 5 | 2 | 33 | 1,100 | 90 | 32 | **M** | **M** | 55 | 98 | 24 |
| Thung Kha Bay - Savi Bay | 3,543 | 4 | 34 | 23 | 1,628 | 90 | 58 | **M** | **M** | 36 | 13 | 8 |
| Pak Phanang Bay | 8,832 | 3 | 2 | 25 | 1,282 | 56 | 36 | **M** | **M** | 85 | 72 | 45 |
| Kung Kraben Bay | 640 | 2 | 0 | 27 | 6,100 | 80 | 19 | **M** | **M** | 35 | 75 | 16 |
| Welu River Estuary | 5,478 | 3 | 31 | 33 | 1,400 | 60 | 25 | **M** | **M** | 52 | 69 | 15 |
| Tien Yen | 2,537 | 2 | -25 | 13 | 7,000 | 60 | 51 | **M** | **M** | 79 | **M** | **M** |
| Xuan Thuy | 1,775 | 3 | 98 | 11 | 9,500 | 75 | 61 | 25 | 30 | 90 | 31 | 62 |
| Can Gio | 8,958 | 3 | 100 | 32 | 6,000 | 80 | 28 | 17 | 32 | 103 | 96 | 34 |
| Ca Mau | 5,239 | 3 | 60 | 30 | 7,500 | 85 | 12 | 6 | 15 | 36 | 18 | 53 |
| Shangkou | 812 | 4 | 11 | 9 | 11,980 | 90 | 65 | 40 | 33 | 95 | 28 | 76 |
| Quinglangang | 1,189 | 6 | -56 | 25 | 10,183 | 80 | 60 | 50 | 62 | 90 | 39 | 32 |
| DongXhaiGang | 1,513 | 5 | -14 | 16 | 8,433 | 80 | 32 | 24 | 27 | 84 | 43 | 35 |
| Futien | 82 | 3 | -26 | 7 | 10,233 | 80 | 29 | 16 | 21 | 11 | 58 | 99 |
| Fangchenggang | 1,415 | 4 | -10 | 10 | 12,300 | 90 | 67 | 62 | 40 | 71 | 42 | 145 |
| Busuanga | 1,298 | 5 | -5 | 24 | 7,550 | 90 | 6 | 15 | 36 | 9 | 45 | 27 |
| Coron | 1,296 | 5 | -50 | 26 | 7,080 | **M** | 7 | 15 | 37 | 13 | 42 | 34 |
| San Vicente | 133 | 5 | -15 | 14 | 3,780 | 80 | 6 | 15 | 36 | 13 | 36 | 40 |
| Ulugan | 790 | 4 | -10 | 16 | 5,100 | 85 | 8 | 15 | 36 | 13 | 42 | 39 |
| San Jose | 483 | 4 | -80 | 25 | 3,180 | 60 | 7 | 13 | 34 | 7 | 48 | 37 |
| Subic | 148 | 3 | -20 | 23 | 1,420 | 90 | 8 | 14 | 35 | 16 | 44 | 57 |
| Quezon | 1,939 | 5 | -40 | 32 | 4,000 | 80 | 5 | 14 | 37 | 11 | 44 | 37 |
| Belitung Island | 22,457 | 5 | 0 | 8 | 467 | 100 | 5 | 26 | 43 | 71 | **M** | **M** |
| Angke Kaput | 328 | 9 | -2 | 12 | 569 | 70 | 29 | 21 | 4 | 22 | 40 | 4 |
| Batu Ampar | 65,585 | 5 | 0 | 21 | 2,391 | 100 | 11 | 15 | 17 | 51 | 19 | 27 |
| Ngurah Rai | 1,374 | 6 | 27 | 25 | 660 | 100 | 38 | 10 | 32 | 34 | 38 | 42 |
| Bengkalis | 42,459 | 7 | -15 | 18 | 490 | 99 | 12 | 8 | 9 | 3 | 16 | 15 |

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