REGIONAL COORDINATING UNIT
EAST ASIAN SEAS ACTION PLAN

UNEP UNITED NATIONS ENVIRONMENT PROGRAMME

Integrated Management of Watersheds in Relation to Management and Conservation of Nearshore Coastal and Marine Areas in the East Asian Seas Region: Phase 1 - Assessment of Effects of River Discharges of Sediments, Nutrients and Pollutants on Coastal Wetlands, Seagrass Beds and Coral Reefs

A Regional Overview

RCU/EAS TECHNICAL REPORTS SERIES NO. 13

UNEP
Bangkok, August 1997

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FOREWORD

The East Asian Seas (EAS) Region contains some richest areas in the world in terms of biodiversity. This region contains the greatest numbers of species of corals, seagrasses, and mangroves which are interlinked in complex and highly productive ecosystems. These important coastal and marine ecosystems, however, are coming under increasing pressure from the rapid development taking place in the region. This development has involved significant land-use changes in coastal areas and within inland watersheds.

The degradation of coastal and marine environments has been attributed largely to land-based activities. Freshwater moves through watersheds, carrying with it sediments, nutrients, and pollutants from terrestrial sources and then flows through coastal areas to the oceans. To mitigate the impacts that result from sediment, nutrient, and pollution accumulation in the coastal and marine environment, measures taken in the coastal and marine environment alone are not sufficient to alleviate the degraded condition of these ecosystems. An integrated management system has to be devised to address the causes of degradation. Thus, management measures within watersheds are necessary to protect the downstream coastal and marine ecosystems which are significantly impacted by land-based sources of sediments, nutrients, and pollutants.

This document is an overview of the current state of coral reefs, seagrass beds, and coastal wetlands in Australia, Kingdom of Cambodia, People's Republic of China, Indonesia, Republic of Korea, Malaysia, the Philippines, Singapore, Thailand, and Socialist Republic of Vietnam. It also presents information from the countries concerning the status of watersheds and the sources of sediment, nutrients, and pollution within them that ultimately affect coastal and marine environments. It represents the first step towards attaining a better understanding of the interlinkages between land-based sources of sediments, nutrients, and pollutants, their movement through watersheds, and their impacts on coastal and marine environments. Most importantly, however, this overview embodies the realization that terrestrial, freshwater, and marine ecosystems in the East Asian Seas Region need to be addressed and managed in an integrated and holistic manner to allow development and the fulfillment of human needs to occur in a way that is environmentally sustainable.

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PREFACE
A SHORT HISTORY AND ACKNOWLEDGEMENTS

The EAS-35 Project, "Integrated Management of Watersheds in Relation to Management and Conservation of Nearshore Coastal and Marine Areas in the East Asian Seas Region: Phase 1 - Assessment of Effects of River Discharges of Sediments, Nutrients and Pollutants on Coastal Wetlands, Seagrass Beds and Coral Reefs", was approved by the Eleventh Meeting of the Coordinating Body on the Seas of East Asia (COBSEA) in October, 1994. The EAS-35 Project was the first collaborative effort of United Nations Environment Programme's (UNEP) Freshwater Unit (FWU) and the Regional Coordinating Unit for East Asian Seas (EAS/RCU). It was the first project between the FWU and UNEP's Ocean and Coastal Areas Programme Activity Centre (OCA/PAC) (these are now combined in the UNEP Water Branch) that sought to develop an integrated approach to the management of the coastal and marine environments with regard to land-based sources of sediments, nutrients, and pollutants (SNP). The EAS-35 Project builds on other UNEP initiatives to mitigate land-based sources of SNP. These projects are outlined below:

EAS-19	Development of Management Plans for Endangered Coastal and Marine Living Resources in East Asia (first phase of EAS-25)
EAS-21	Assessment of Land-based Urban, Industrial, and Agricultural Sources of Pollution; their Environmental Impact; and Development of Recommendations for Possible Control Measures
EAS-25 .	Phase II: Development of Management Plans for Endangered Coastal and Marine Living Resources in East Asia (see RCU/EAS Technical Reports Series No. 4 - Staff Training Materials for the Management of Marine Protected Areas
EAS-27	Programme of Action to Control Land-based Sources of Pollution in the East Asian Seas Region (see RCU/EAS Technical Reports Series No. 5 - Regional Programme of Action on Land-based Activities Affecting Coastal and Marine Areas in the East Asian Seas)
EAS-33	Biological Impacts of Pollutants (see RCU/EAS Technical Reports Series Nos. 3, 7 and 9 - Proceedings of the Workshop on Soft-bottom Benthic Communities as Indicators of Pollutant-induced Changes in the Marine Environment)

Within the framework of the EAS-35 Project, the participating countries, Australia, Kingdom of Cambodia, People's Republic of China, Indonesia, Republic of Korea, Malaysia, the Philippines, Singapore, Thailand, and Socialist Republic of Vietnam, prepared national inventories and site specific synopses, with the purpose of exploring the linkages between the land-based sources of sediments, nutrients, and pollutants within watersheds and their impacts on the coastal and marine environments. The 'national inventories' and 'synopses' were presented at the First Workshop of the EAS-35 Project held in Bangkok, 3-7 April 1995. In order to establish the linkage of activities upstream with conditions downstream, one 'ecological site' having the four management units, a watershed, coral reef, seagrass bed, and coastal wetland ecosystem, was to be selected and analyzed as one integrated system.

This document synthesizes the national inventories and synopses in four thematic overviews on coral reefs, seagrass beds, coastal wetlands, and watersheds and attempts to focus on the linkages between the sources of SNP in the watersheds and their impacts on the coastal and marine environment. The second Workshop of the EAS-35 Project was held in Bangkok, 16-20 October 1995. This workshop led to the realization that there should be an integrative chapter in the technical report to illustrate the linkage of watershed conditions or activities with the environmental conditions in coastal wetlands, seagrass beds, and coral reefs.

The thematic overviews present information on coastal and marine ecosystems as they were reported in the national inventories from the project participants. Some of the inventories were general in approach, giving information for the entire country but not detailing conditions in a specific area of study. This is explained by the current incipient state of research on coastal and marine ecosystems in this region. In such cases, data and information from other sources that could provide additional detail may have been included.

With respect to watersheds, it was realized that given the wide scope of the national task to cover all watersheds, the national inventories should focus in some detail on one to three watershed(s) in each country. As a result, the national inventories on watersheds cannot be considered as representative of the actual overall situation in the countries concerned, yet they provide good insight into the level of information available and into the generic problems related to assessing the sources of SNP. Nevertheless, the thematic overview on watersheds gives an indication of the situation in the ten participating countries in the EAS region.

Many persons are responsible for the completion of this Regional Overview for the Integrated Management of Watersheds in Relation to Management and Conservation of Nearshore Coastal and Marine Areas in East Asian Seas Region: Phase 1 - Assessment of Effects of River Discharges of Sediments, Nutrients, and Pollutants on Coastal Wetlands, Seagrass Beds, and Coral Reefs. The following individuals were instrumental in preparing the document:

Section 1 - Stephen Hillman, Great Barrier Marine Reef Park Authority; Townsville, Queensland, Australia

Section 2 - Miguel Fortes, University of the Philippines; Quezon City, Philippines

Section 3 - Peter K. L. Ng, The National University of Singapore; Singapore

Section 4 - Jacobus Zeper, Consultant to the EAS/RCU, UNEP; Bangkok, Thailand

Section 5 - Annadel Cabanban, Universiti Malaysia Sabah; Kota Kinabalu, Sabah, Malaysia

In addition to the above, the following persons provided tremendous assistance in the preparation, reviewing and finalization of the document: Habib N. El-Habr and Kim-Looi Ch'ng (EAS/RCU), Walter Rast, Gerhart Schneider and David Smith (UNEP/Water Branch), Jeff Thornton, Charles Davis, and Steve Arquitt. Special appreciation goes to Unchalee Kattachan (EAS/RCU) for her patience and assistance with word processing and formatting.

The final editing was done by Mr. Thomas Panella, The University of California at Berkeley; Berkeley, California, USA.

Sincere gratitude is also expressed to those who participated in the workshops and to the national representatives (focal points). Thanks is especially given to those persons who were directly responsible for the tremendous effort and time spent preparing and finalizing the national inventories. While the task was difficult, largely due to the lack of information, these inventories now add substantial information that can serve as a basis for future efforts to address critical issues on the integrated management of watersheds in regard to coastal and marine environments.

OVERVIEW OF CORAL REEFS, SEAGRASS BEDS COASTAL WETLANDS AND WATERSHEDS IN THE EAST ASIAN SEAS REGION

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SECTION 1. CORAL REEFS IN THE EAST ASIAN SEAS REGION

1.1 INTRODUCTION

1.1.1 Status of Coral Reefs in the Region

The status of coral reefs in the East Asian Seas region varies significantly both within the jurisdiction of individual countries and between countries. Each condition reflects: the extent of development on adjacent coastlines; the direct effects of improper use of the reefs themselves; and the natural distribution of reefs. The importance of maintaining healthy reefs for sustainable use was emphasized by all contributing nations.

Generally speaking, with the possible exception of reefs in Australia (where the extent of reef systems is large and the coastline development is relatively small by Asian standards), most reefs in the region are either degraded already or at risk of degradation. Even in the case of Australian reefs, many are at risk from mainland pollution in the form of sedimentation, nutrient-loading, and freshwater intrusion from run-off. The Proceedings of the Third ASEAN-Australia Symposium on Living Coastal Resources in 1994 notes that less than 20% of reefs that were surveyed in the ASEAN region are in healthy condition, based on live coral cover exceeding 75%.

The inventories demonstrate that coral reefs are important social and economic assets through their support of fisheries and vital ecological systems of the world's biodiversity. The inventories also indicate that coral reefs, in many areas, are at a crisis point in terms of their ability to provide the necessary benefits to those who rely upon them. Despite the lack of explicit scientific information that is apparent in many parts of the region, all participants documented the fact that enough is now known to call for management action that protects and attempts to restore the remaining coral reef resources.

1.1.2 Factors Attributed to Coral Reef Degradation

Factors associated with coral reef degradation in the EAS region include:

- excess sediment levels from land-use modification, construction, and water-course alteration;
- excess nutrient levels from sewage and fertilizer run-off;
- excess pollution levels from domestic and industrial wastewater run-off;
- increased freshwater run-off from watershed modification;
- blast-fishing (dynamite);
- anchor damage;
- mining of coral;
- poison use in fishing;

- muro-ami fishing[1] ;
- removal of mangroves, and
- aquaculture development.

These factors may occur individually or a number of them may occur at the same time. Although difficult to quantify, it is likely the cumulative effects of several factors may cause reefs more damage than one would expect from a purely additive effect of impacts.

The factors causing degradation presented above are well-known but have been difficult to control due to a number of underlying causes such as: the lack of education; lack of appropriate legal and institutional frameworks and law enforcement difficulties; multiple tiers of government; over-riding economic considerations, and sectoral management.

1.2 REGIONAL ASSESSMENT

1.2.1 Extent of the Problems of Sedimentation, Nutrient-Loading, and Pollution

All countries have identified major adverse impacts on their coral reefs. The most consistently identified problems attributable to mainland run-off were excess sedimentation, eutrophication, and freshwater influx. Major developments (or the incremental effects of a number of small developments) are modifying the land's ability to retain sediment and nutrients which have demonstrated potential to harm the reefs downstream.

Increased sediment loads lead to higher turbidity with less light available for bottom communities and disturbance to bottom fauna due to siltation. Coral reefs may be affected by even moderate increases in sedimentation and turbidity. Corals need light for their symbiotic algae (zooxanthellae) to function. In no country is this better illustrated than Indonesia. In Jakarta Bay, Indonesia, the maximum depth at which corals occurred was 9 m in 1929, but was reduced to a mean of 4 m by 1993. Historical data show a marked spreading of the sphere of influence of river-sourced sediments between 1929 and 1993. Coral cover decreased from a mean of 30% in 1985 to less than 5% in 1995. Species richness of corals declined at one site from 96 to 16 species between 1929 and 1993. Similar dramatic effects have been noted on fish populations.

Excess nutrients can have a number of effects on coral reef systems. Nitrogen or phosphorus are often limiting nutrients for the growth of phytoplankton, especially in warm, clear tropical waters where light is unlikely to be limiting. Thus, phytoplankton flourishes in nutrient enhanced conditions, leading to decreased water clarity and reduced light for coral growth on the bottom. The increase in phytoplankton also encourages the growth of filter-feeding organisms such as sponges, tube worms, and barnacles which compete for space with coral. As many of these organisms bore into the coral reef structure, enhanced reef bioerosion may occur, leading to the loss of reef structural integrity. In addition, nutrients enhance the growth of turf and macroalgae which overgrow the coral, competing for space and shading the colonies. These dramatic impacts are the consequences of eutrophication and are evident in Jakarta Bay, where large scale plankton blooms occur and coral reefs have essentially been replaced by a benthic community dominated by filter-feeders and detritus- feeders. Boring molluscs are also now rapidly destroying the limestone reef matrix.

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[1] "Muro-ami" fishing makes use of heavy stones weighing approximately 2 kg which are used to pound the reef structure with the intent of frightening fish into drive-in nets.

Excessive freshwater inputs that result from heavy rain can lower salinity in the coastal zone to such an extent and for a long enough period that coral reefs can be severely degraded. It is likely that there is a synergistic effect with temperature since corals may be under stress from elevated temperatures during summer when the rains occur. Light attenuation due to turbidity further stresses the coral communities.

The extent of the problems vary widely within the region, but overall, coral reefs are in an unacceptably degraded state and the risk of further degradation is increasing. That this can happen within a very short time frame indicates that effective management systems urgently need to be put in place as soon as possible. There is no doubt that inappropriate watershed management with increasing sources of mainland run-off are substantially responsible for the problem and should be addressed in an overall holistic, and comprehensive management package.

1.2.2 Management and Mitigation Measures

All participating countries have taken steps to establish national marine protected areas. However, some countries have documented that declaring national parks has resulted in increased tourism which can adversely impact coral reefs. It is acknowledged in the inventories that the declaration of marine parks will only successfully protect reefs if the declaration is part of an overall holistic and comprehensive management package that addresses issues that may be quite remote from the park itself, for example: over-harvesting of trees including those distant in watersheds; clearing of mangroves for aquaculture purposes; as well as issues not associated with mainland activities such as blast-fishing. The overall cumulative effects of stress on coral reefs from numerous impacts are such that a holistic management approach is essential.

Most countries have now put in place, or are putting in place, action plans to protect their coral reef resources. These plans may be directed to better enforcement of regulations that already exist; the development of new regulatory measures; or a combination of both. It is important to note that education of those likely to damage reefs in their immediate vicinity is seen as a priority task. The difficulties associated with managing more remote sources of impacts have been acknowledged in the inventories, and many levels of government and sectors, require coordination if management of these problems is to be achieved. A recent IUCN - CNPPA report estimated that less than 10% of marine protected areas in the East Asian Seas Region are fulfilling their management objectives.

There is a need for governments to strengthen support of present management agencies that have responsibilities to coordinate and focus the attention of stake-holders organizations, communities, and individuals to address the management of watersheds, coastal areas, and the marine environment in a holistic fashion. It may be appropriate to establish new agencies to coordinate these tasks yet this should only been seen as a last resort if it is impossible to adapt the existing institutional framework. It is particularly important that stake-holders have a high degree of input into the development of management plans and are thus committed to their implementation and success.

Effective management and mitigation will only occur if the conservation principles are supported, and policies are developed and implementation endorsed at the highest levels of government.

1.3 NEEDS

1.3.1 Knowledge

In order to address the sustainable management of coral reefs, the following knowledge enhancing actions should be taken:

- Develop quantifiable techniques of assessing the values of coral reefs in economic, social, and ecological contexts;
- Determine the actual levels of nutrients and sediment that are injurious to reefs. Work is underway to address this question, although it should be noted that differences in species response will make it difficult to establish a specific set of standards for water quality;
- Identify appropriate indicator species for each area;
- Develop baseline information through a long-term monitoring programme with which to assess human-induced changes within a recognized framework of natural variability. This is an essential first step in scientific reef management and has been embarked upon by a number of countries;
- Improve prediction of river outflow plume zones which would help assess risks to various reef resources; and
- Determine natural versus man-induced sediment levels.

1.3.2 Management

Each country must examine the options available in regard to management measures that can be applied to coral reefs within the context of its own political and social systems.

All countries have acknowledged that management responses needed better coordination. Many have considerable legal measures to control individual aspects of impacts on coral reefs but do not have the infrastructure in place to actually carry out the task. This may be a result of several factors including:

- lack of resources (qualified personnel, funding, equipment, and so on);
- different goals and strategies supported by different departments; and
- many tiers of government with overlapping responsibilities.

1.3.3 Policy

Reef-related policies have not been elaborated upon by participant countries either because they are implicit or do not exist. Given the number of management initiatives that are being implemented, it appears that policies do exist but are probably piecemeal at various levels within governments.

Policies should be developed with as wide a consultative process as is reasonable. High-level qualitative policies such as, a commitment to increasing the levels of reef protection, and the minimizing of water quality degradation, could be promoted and require no more than a commitment to conservation principles. However, the difficulties that may arise in policy development cannot be underestimated, and it is particularly hard to have consistent policies across all areas of government.

In order to ensure long-term national benefits from coral reefs, it is important that stakeholders at every level have the opportunity to provide input into the formulation of policies and strategies for sustainable management.

1.4 CONCLUSIONS

There is a pressing need for improved management of coral reefs on all levels, and that management must look to the mainland as a primary source of the adverse impacts on reefs.

The conclusion that one comes to at first glance is that of concern that the coral reefs in the region have been so adversely mismanaged over the past few decades. It is especially disturbing that monitoring initiatives that have documented the ongoing decline have not triggered effective management responses. Many countries throughout the region, however, are faced with considerable difficulties in implementing management strategies. Despite the importance of addressing the issues, the long-term values of coral reefs have not been adequately balanced against short-term economic gains.

It is, however, encouraging to find a high level of awareness of both the importance of coral reefs and the state to which they have been degraded as a result of adverse impacts. It is also promising to find strong support for management in the absence of quantitative analysis of the inter-relationships between the sources of impacts and measurable impacts themselves. This commitment to the precautionary principle[2] gives hope for the halting, and also the eventual reversal, of recent trends in coral reef degradation.

It is also necessary for development strategies to be created within the context of ecologically sustainable use. These strategies should incorporate the dynamic carrying capacities of the coral reef ecosystems.

1.5 RECOMMENDATIONS

Accepting that coral reefs are important economic and social assets and critical biodiversity components of the countries of the East Asian Seas; and acknowledging that a large proportion of the region's coral reefs are currently degraded or threatened with degradation, it is recommended that:

- Governments throughout the region adopt an integrated approach to planning development that can effectively establish and implement multi-sectoral and integrated planning and management measures to mitigate against the degradation of coral reefs;

- Governments throughout the region take advantage of the current international initiatives that are developing, or that have been developed, so that duplication of effort is minimized. These programmes include: the EAS series projects as they relate to coral reef management and other topics that have relevance to coral reefs; the International Coral Reef Initiative, which is intended to focus attention on coral reef issues and to coordinate priorities, approaches, and funding.

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[2] In Agenda 21, Principle 15 describes the Precautionary Principle as follows: "Where there are threats of serious or irreversible damage, a lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation".

- Management action takes place in parallel with the expenditure of resources to document reef condition and monitor reefs.

1.6 SYNOPSES OF COUNTRY INVENTORIES

As part of the East Asian Regional Seas Programme, the United Nations Environment Programme established a project to examine the downstream effects of human activities in watersheds on related coastal and marine ecosystems, including coral reefs. At a workshop held in Bangkok in April 1995, it was decided that the participating countries would prepare inventories of representative watersheds that could be associated with downstream effects. These adverse effects were termed 'insults' to the environment caused by less than optimal watershed management.

This section attempts to synthesize the inputs from the participating countries with a view to providing a consolidated report that draws attention to the present plight of coral reefs in the region. It also aims to encourage governments and other relevant bodies to address the impacts that are being experienced by coral reefs as a result of poor or inappropriate management of watershed activities that may be at considerable distances from the adversely affected coral reefs.

1.6.1 Australia

As the site for its inventory, Australia chose the Herbert River watershed. See Figure 1.1. The sources of threats to the reef systems are the extensive modification of sub-catchments within the watershed by forestry, urbanization, and agriculture. Recognition of the potential problems of land degradation occurred some time ago despite sparse scientific evidence of the effects of nutrient and sediment loads on coral reefs. Studies in the area show that while agricultural activity has raised nutrient content of riverine sediments, the effect is localized and does not extend far across the Great Barrier Reef shelf. The report notes that in general there has been a fourfold increase in sediment and nutrient export from the coast since the time of European settlement. See Figures 1.2, 1.3, and 1.4 and Tables 1.1 and 1.2.

In the inventory site, it is noted that flood plumes can result in nutrient and phytoplankton levels far in excess of non-flood conditions. Following cyclones in 1994 (Cyclone Sadie) and 1995 (Cyclone Violet), the freshwater plumes were observed and sampled. Due to weather conditions, particularly wind direction and strength, the dispersion of the plumes was very different for the two events. This occurred despite the fact that the amount and duration of rainfall was similar for both events. The 1994 event resulted in a single water mass extending from Townsville to Port Douglas (ca. 320 km). The plume dispersed as much as 100 km offshore and impacted many mid-shelf coral reefs. The total area of the plume was 14,000 km^2. Coral bleaching was extensive on a number of reefs offshore from the river mouth down to a depth of at least 9 m. Most reefs are recovering, although for some coral species at least 30% mortality was noted.

The 1995 cyclone and flood event was subjected to much more extensive investigation in terms of water quality parameters than the 1994 flood event. In this instance, the primary plume generally lay within 10 km of the coast, and it is unlikely that many midshelf reefs were affected. Some secondary plumes extended out as much as 30 km offshore. Although a much more intensive investigation took place, the event has yet to be correlated with significant impacts to coral reefs. See Figure 1.5 for plume locations.

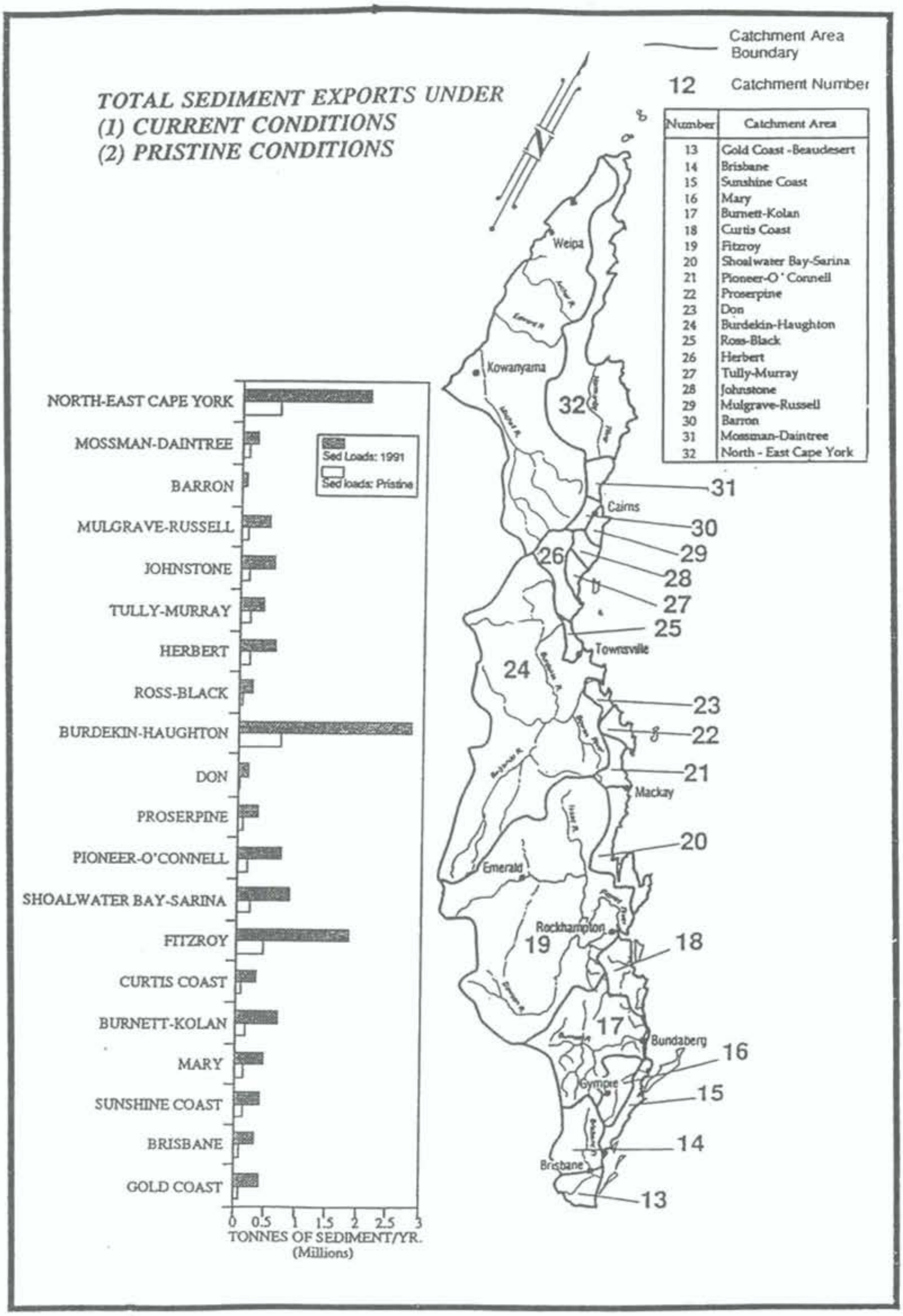
The inventory suggests that while it is difficult to attribute the amount of run-off to man-induced changes, it is clear that coral reefs are adversely affected by the cyclones and resulting floods. It seems prudent, therefore, to attempt to minimize increases in the quantity of water, sediments, and nutrients attributable to human activity emanating from rivers.

Table 1.1 Estimated annual sediment export loads in coastal Queensland according to source: natural (pristine), grazing, cropping, and urban.

Catchment	Sediment Loads (1000 tonnes)				
	Pristine	Grazing	Cropping	Urban	Total
Gold Coast	9	370	29	13	421
Brisbane	12	264	31	40	347
Sunshine Coast	62	331	37	2	432
Mary	53	351	80	2	486
Burnett-Kolan	32	599	64	2	698
Curtis Coast	13	336	5	1	355
Fitzroy	41	1589	229	2	1861
Shoalwater Bay-Sarina	52	712	9	0	863
Pioneer-O'Connell	32	464	223	1	720
Proserpine	20	260	58	0	338
Don	1	176	5	0	182
Burdekin-Kaughton	12	2741	73	2	2829
Ross-Black	13	223	2	4	242
Herbert	23	462	64	1	550
Tully-Murray	113	196	92	0	401
Johnstone	60	271	235	1	567
Mulgrave-Russell	66	192	212	1	471
Barron	15	75	20	4	114
Mossman-Daintree	104	111	52	1	268
North-east Cape York	130	1963	3	0	2096

Source: Kirkman, 1995

Figure 1.2 **Change in total sediment exports from pristine to current conditions in coastal Queensland catchments.**



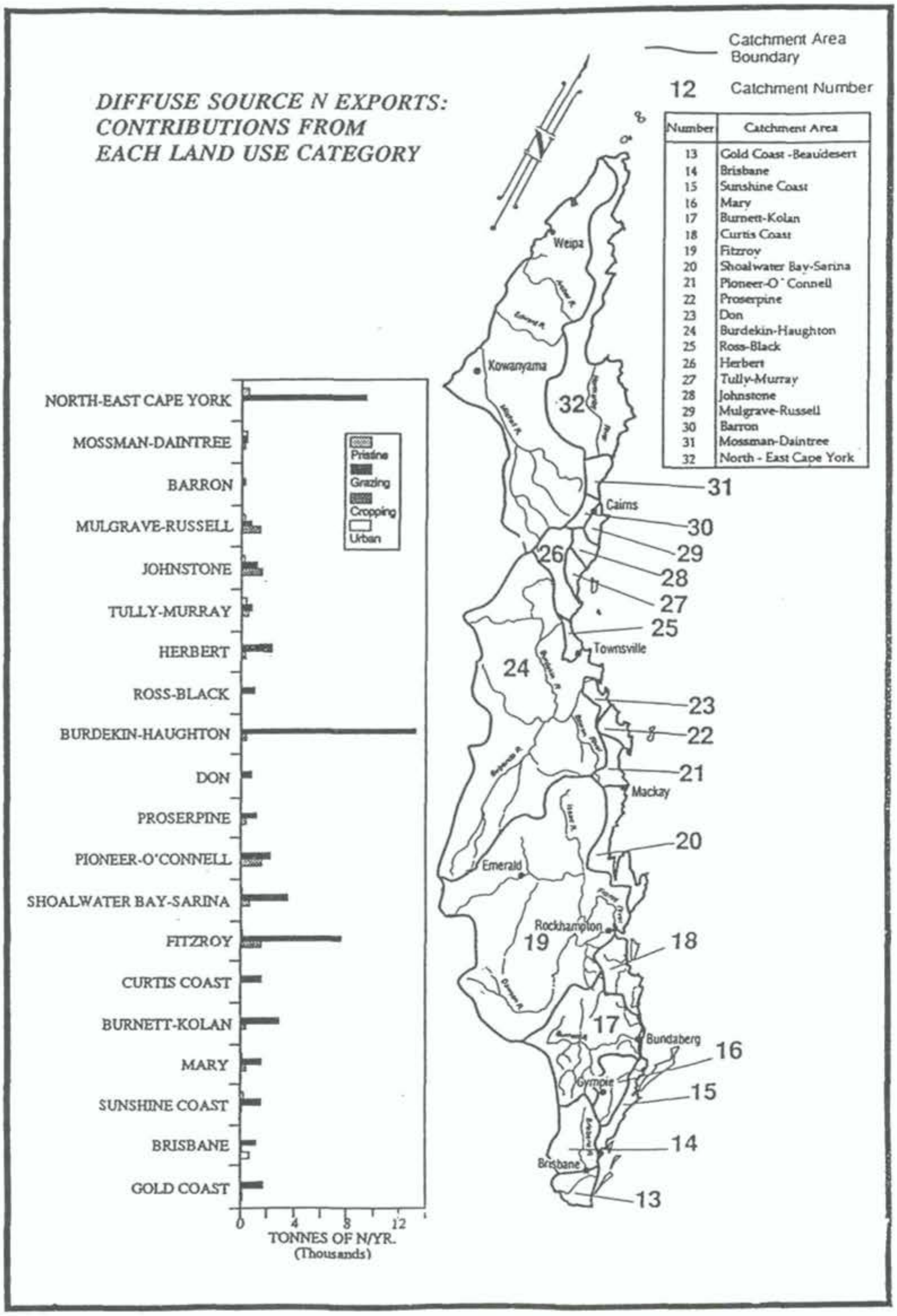
Source: Kirkman, 1995

Table 1.2 **Estimated annual nitrogen and phosphorus export loads in coastal Queensland according to source: natural (pristine), grazing, cropping, and urban.**

Catchment	Annual Nitrogen Loads (tonnes)					Annual Phosphorus Loads (tonnes)				
	Pristine	Grazing	Cropping	Urban	Total	Pristine	Grazing	Cropping	Urban	Total
Gold Coast	44	1793	203	237	**2277**	6	256	30	22	**314**
Brisbane	60	1278	212	740	**2290**	9	183	32	70	**294**
Sunshine Coast	300	1603	259	37	**2199**	43	229	39	4	**315**
Mary	257	1703	553	30	**2543**	37	243	83	3	**366**
Burnett-Kolan	155	2905	447	30	**3537**	22	415	67	3	**507**
Curtis Coast	62	1627	32	22	**1743**	9	232	5	2	**248**
Fitzroy	200	7698	1582	37	**9517**	29	1100	237	4	**1370**
Shoalwater Bay-Sarina	254	3449	686	7	**4396**	36	493	103	1	**633**
Pioneer-O'Connell	157	2251	1546	22	**3976**	22	322	232	2	**578**
Proserpine	97	1258	403	4	**1762**	14	180	60	0	**254**
Don	5	852	32	7	**896**	1	122	5	1	**129**
Burdekin-Haughton	60	13284	506	37	**13887**	9	1898	76	4	**1987**
Ross-Black	63	1079	17	74	**1233**	9	154	3	7	**173**
Herbert	110	2241	443	11	**2805**	16	320	66	1	**403**
Tully-Murray	550	949	637	7	**2143**	79	136	96	1	**312**
Johnstone	291	1315	1629	15	**3250**	42	188	244	1	**475**
Mulgrave-Russell	321	930	1464	11	**2726**	46	133	220	1	**400**
Barron	72	363	138	74	**647**	10	52	21	7	**90**
Mossman-Daintree	506	528	358	11	**1413**	72	77	54	1	**204**
North-East Cape York	628	9511	22	7	**10168**	90	1359	3	1	**1453**

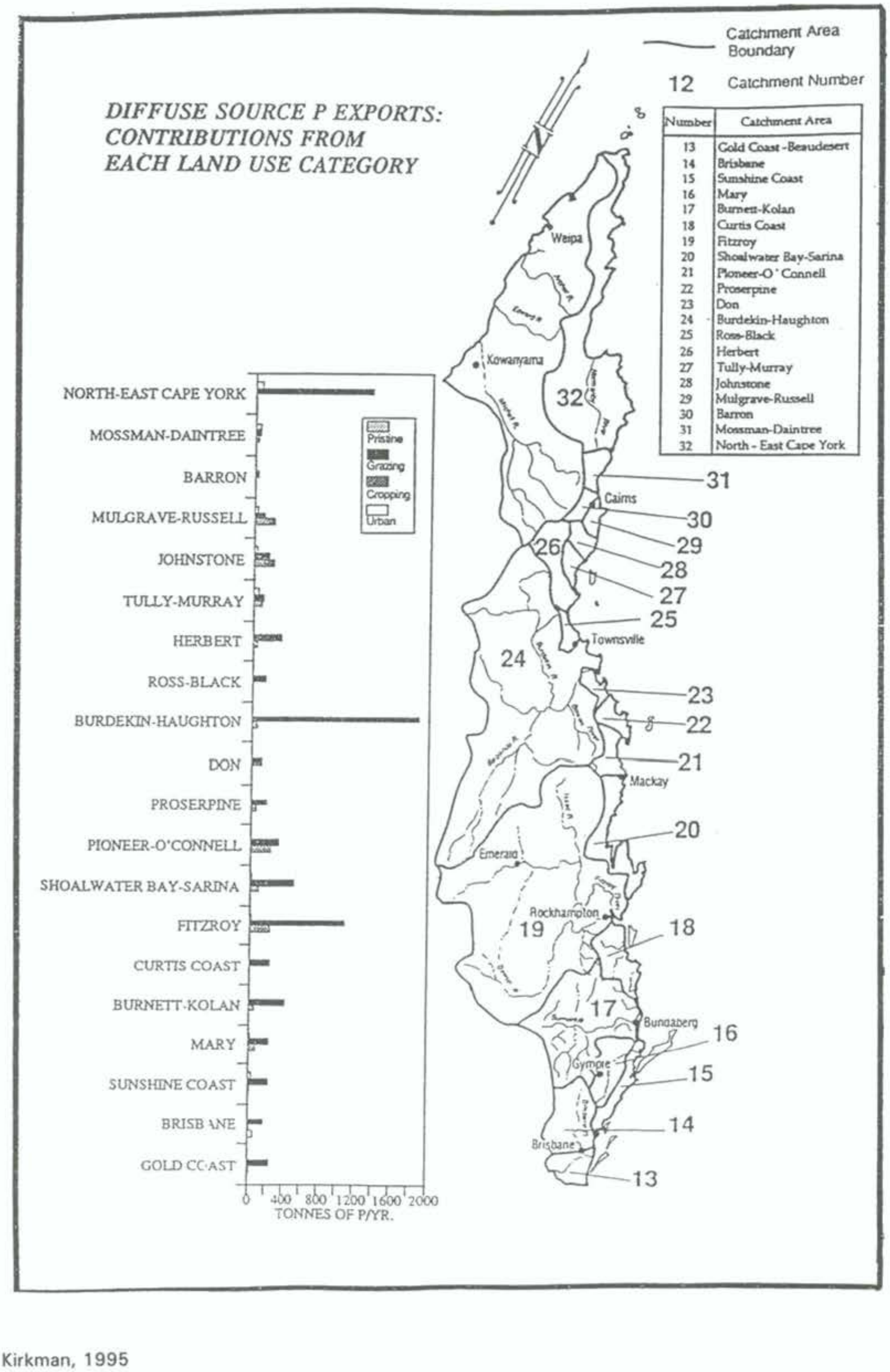
Source: Kirkman, 1995

Figure 1.3 Current contributions of diffuse source nitrogen exports by land-use category in coastal Queensland.



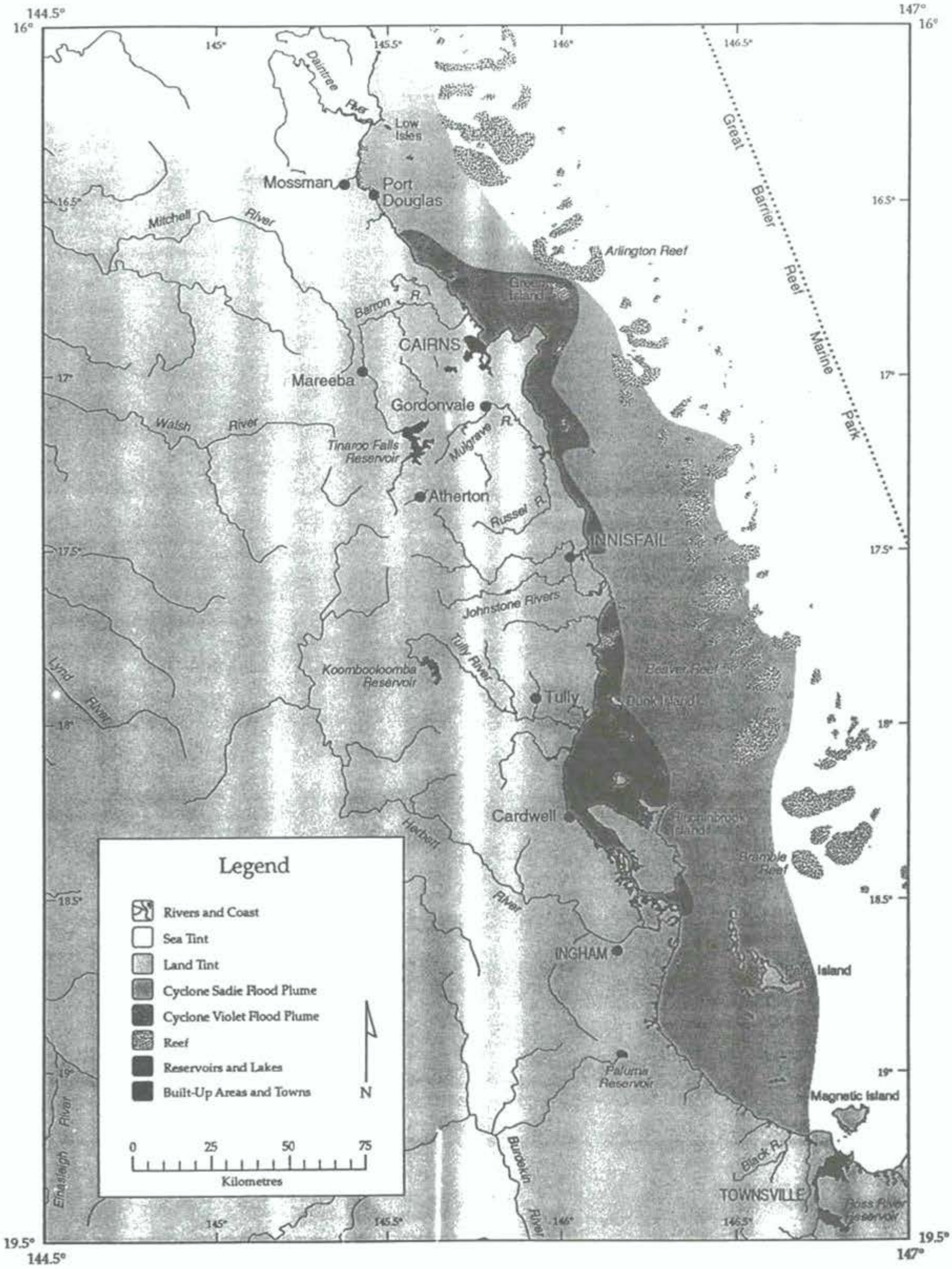
Source: Kirkman, 1995

Figure 1.4 Current contributions of diffuse source phosphorus exports by land-use category in coastal Queensland.



Source: Kirkman, 1995

Figure 1.5 Areal extent of Cyclone Sadie and Violet Flood plumes.



Source: Hillman, 1995

Identified gaps in knowledge were found to be:

- the need to develop baseline information to form a framework of natural variability;
- the need to establish the real level of nutrients and sediments that are injurious to reefs;
- the need to identify and select suitable indicator species; and
- the need to better predict zones of influence of river flood plumes to try and assess risks.

A programme is under way to reduce agricultural sources of sediment and nutrient inputs through the development of integrated catchment management (ICM). The objective of the programme is to have integrated catchment management in place in all coastal catchments by the year 2000. The ICM process will include:

- better land management methods such as stubble retention on cropping lands;
- retention of riparian buffer zones (strips of vegetation along river banks) and wetlands;
- education on the management of grazing lands;
- better fertilizer application technology; and
- green sugarcane harvesting to reduce nutrient and soil losses.

To address the changes that have taken place due to increased nutrient and sediment-loading, a 25 year Strategic Plan for the Great Barrier Reef World Heritage Area has been developed. Monitoring programmes have been designed to:

- detect long-term trends in sediment and nutrient status;
- examine regional differences in sediment and nutrient status;
- quantify cross shelf differences in sediment and nutrient status; and
- monitor the effectiveness of programmes to reduce the inputs of nutrients.

The findings from the Australian national inventory suggest that:

- even in relatively well managed situations there is still potential for unacceptable levels of damage to coral reefs due to natural hazards;
- the unpredictability of plume quantity, content, and dispersal are major difficulties in the setting of effective parameters that can be monitored at the source of the plume, and the entire catchment should be considered as the source of the plume;
- management must take a holistic approach to minimize impacts to coral reefs;
- causal relationships and set parameters do not need to be established before it is wise and necessary to take management action; and
- it is imperative that management plans are initiated, as far as possible, prior to adverse impacts being observed.

1.6.2 Cambodia

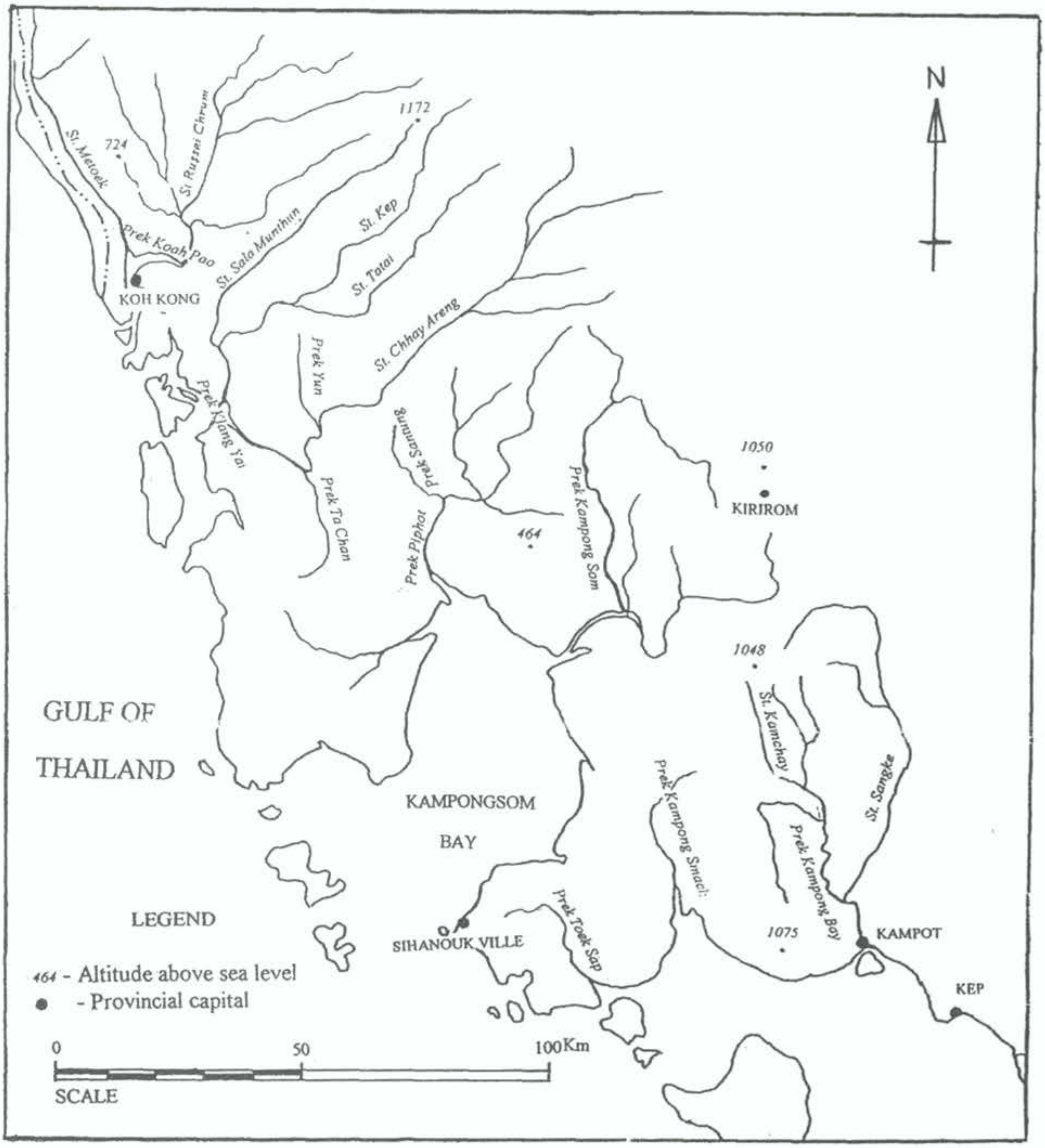
Cambodia is now at a crossroads in its development and needs to initiate protective measures for its coral reefs. At present, Cambodia has a near total absence of an information base about coral reefs. It has a coastline on the Gulf of Thailand extending 435 km in the south west part of the country, and much of the coast is sparsely populated and has suffered little exploitation. The study area chosen is the marine area bordering the provinces of Koh Kong, Kampot, and Sihanouk Ville. See Figure 1.6. These provinces have not had heavy population pressure and remain relatively unexploited although they are under increasing pressure from logging interests. Mangroves have suffered severe deterioration in the recent past.

The inventory describes the general status of coral reefs, although it has not been possible to describe the site in detail. It is acknowledged, however, that reefs are threatened by sedimentation, pollution, nutrients, and freshwater run-off.

Cambodia has developed a national strategy for the conservation of coral reefs and the main elements of this are:

- the survey of coral reefs;
- identification of particular problems;
- detailed studies of flora and fauna;
- preparation of a status report;
- controls on the over-exploitation of corals;
- investigations of the impacts of pollutants;
- regulation of fisheries;
- education and awareness programmes; and
- marine park development and management plans for a number of areas.

Figure 1.6 Coastal areas of Koh Kong, Sihanouk Ville, and Kampot.



Source: Ponlok, 1995

1.6.3 China

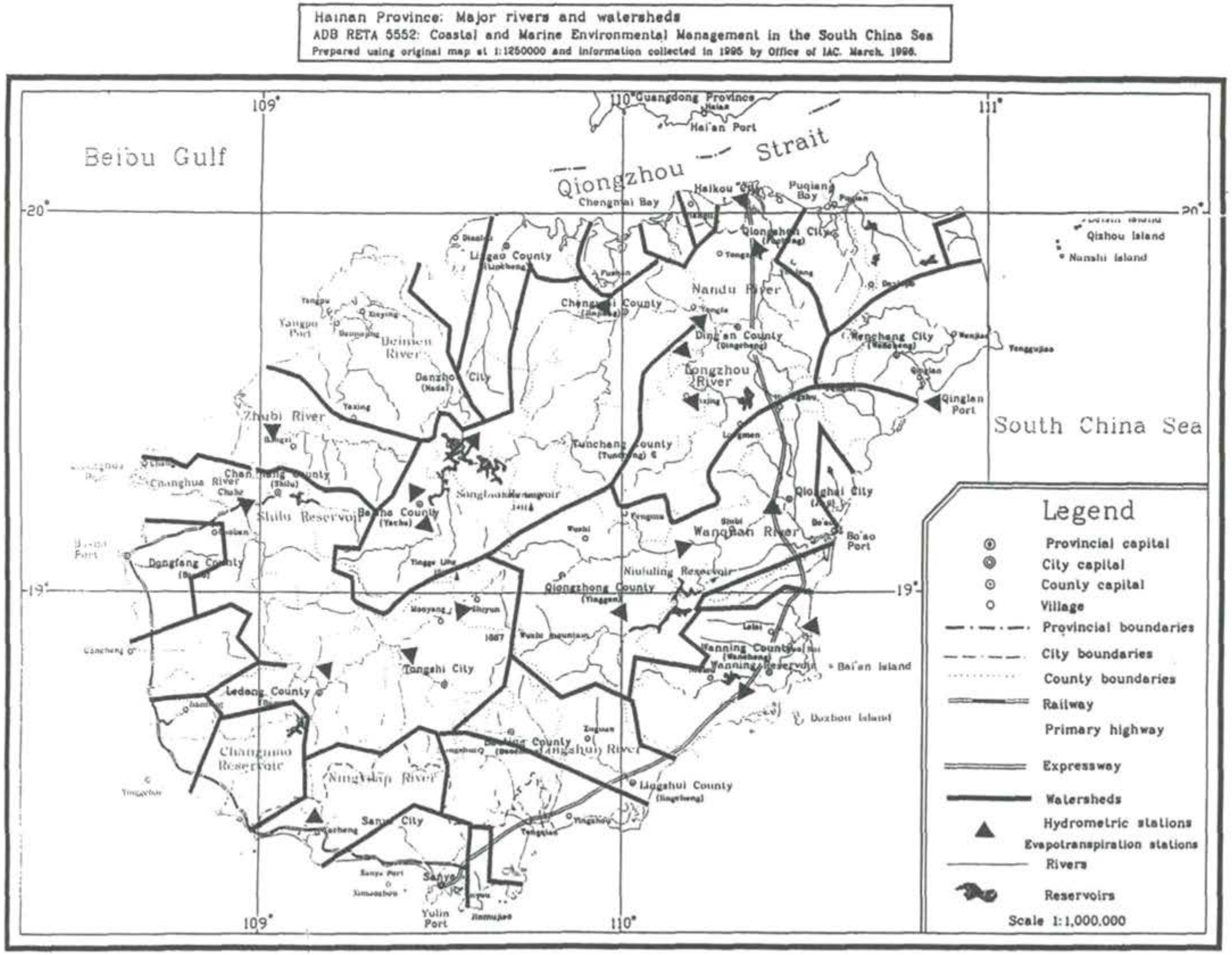
China chose as its primary study site Hainan Island and notes that it is an abundant reserve for coral species. See Figure 1.7. Adjacent to Hainan Island, there is the national reserve of Sanya City, the coral reefs of which were destroyed by human activities, principally the mining of limestone.

The report notes that the destruction of coral reefs can severely impact the adjacent coast since the protection afforded by the reef from sea action is removed. The government has attached great importance to protecting coral reefs and much work has been done to: educate people of the importance of marine resources; establish coral reef reserves; strengthen legislation on marine protection; and address the issue of enforcement.

China, concerned with rapid deterioration of coral reefs, would like to increase its research and monitoring efforts and provide improved information to decision makers so that they better understand the importance of coral reef ecosystems.

The reefs in Sanya are presently being monitored, and better administrative arrangements for protection are being implemented.

Figure 1.7 Map of Hainan Island with major rivers and watersheds.



Source: Asian Development Bank, 1996

1.6.4 Indonesia

Jakarta Bay was chosen as the study site for Indonesia's inventory. This is a particularly suitable site because there are many coral reefs throughout the bay at various distances from the sources of impact. It is therefore possible to get an indication of the relationship between distance from SNP discharge and impact. The Kepulauan Seribu National Park and other islands form a chain extending 80 kilometers and consisting of 110 coral islands. See Figure 1.8.

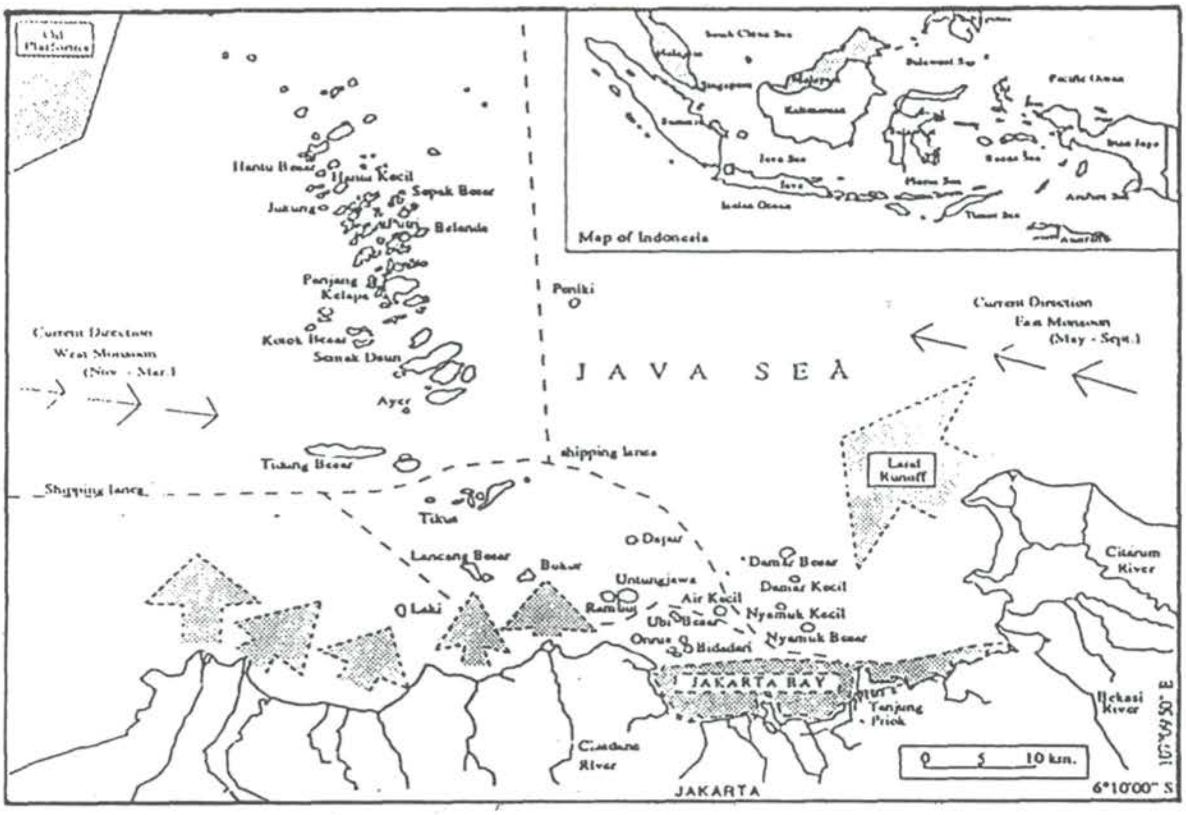
In this case study, clear evidence exists linking effects from the Seribu watershed with adverse impacts on coral reefs. Offshore water turbidity in Jakarta Bay has increased substantially between 1929 and 1993, indicating an increase in the sphere of influence of river-sourced sediments. There is a strong inverse relationship between the extinction coefficient of light measured by Secchi disk and distance from the Java mainland ($r^2 = 0.76$). The percentage of living coral cover is shown to be directly related to water clarity and distance from the mainland. Historical data on coral cover of 28 islands more than 20 km offshore show that reefs which had coral cover of around 30% in 1985 had a mean of less than 5% in 1995. Most reefs have been reduced to rubble. Increased sedimentation has reduced light levels on which coral rely for photosynthesis so that the maximum depth at which corals occur has diminished from a mean of 9 m in 1929 to 4 m in 1993. Species richness has also declined dramatically with one site recording 96 coral species in 1929, but only 16 species in 1993. Data on the number of fish species also strongly correlates with distance from the mainland ($r^2 = 0.82$). One of the largest predatory fish, the Napoleon wrasse, is now almost absent from Jakarta Bay.

Nutrients have also increased dramatically between 1964 and 1992 with a doubling of phosphorous concentrations and a 5 fold increase in nitrate levels. This has resulted in phytoplankton blooms and evidence is emerging that these blooms are spreading further offshore. In 1986, plankton blooms were only detected 2 km offshore, but by 1988, they were seen 5 km offshore and by 1990, plankton blooms were seen 12 km offshore. These algal blooms have caused a fundamental shift in the composition of the benthic community from a coral dominated one to one based on filter-feeding and deposit-feeding animals. Bioerosion is occurring at a rapid rate through the proliferation of boring organisms, such as the bivalve *Lithophaga sp.*, causing rapid destruction of the old limestone reef matrix. The report concludes that the once thriving reefs of Jakarta Bay are now 'functionally dead'.

Heavy metal pollution, mainly copper and lead, from the watershed is also implicated by their concentrations in the sediments with the highest levels occurring near the river mouths.

It is noted that the reefs are indispensable to local fishermen for food fish as well as for the aquarium trade, and that turtle products are consumed (both eggs and adults) and used for the curio trade. Many of these activities take place at an unsustainable level and should therefore be curtailed, except perhaps, where this is a traditional practice occurring at a very low rate. It is also noted that muro-ami fishing takes place. It is not clear from the inventory whether or not this is illegal, but again it should be viewed as unsustainable and endangering the reefs' survival.

Figure 1.8 Map of Jakarta Bay also showing pollution zone.



Source: Hutomo and Dasminto, 1995

1.6.5 Malaysia

Malaysia's coral reefs range from poorly developed ones on the west coast of Peninsular Malaysia to excellent reefs off the coast of Sabah. A general description of all reef qualities is given in the inventory. The majority (64%) of reefs surveyed during the past decade are in fair condition with a coral cover of 25-50%. See Figure 1.9 and Table 1.3 for detail of locations and condition of Malaysian coral reefs.

The report notes that sedimentation is believed to be a primary cause of mortality to corals in the Tunku Abdul Rahman National Park in East Malaysia; on some reefs of Pulau Tioman; and Pulau Redang on the east coast of Peninsular Malaysia. Although quantitative data are lacking, this sediment is believed to be the result of excessive erosion from logging, agriculture, tourism development, clearing for industrial and urban estates, and port dredging. Land reclamation is also noted as problem. Overall, the west coast of Peninsular Malaysia is noted as suffering from medium to high levels of sediment stress; the east coast of Peninsula Malaysia as being under some stress, and East Malaysia as being under medium level of sediment stress. A similar geographic pattern of reef stress is attributed to industrial pollution and dredging.

Exacerbating watershed related impacts are the facts that many reefs have been damaged by blast fishing around Sabah in East Malaysia and by crown-of-thorns starfish outbreaks along the west coast of Peninsular Malaysia. Crown of thorns starfish outbreaks are interesting to the scientific community because there is considerable debate as to whether the outbreaks may be exacerbated by elevated nutrient levels which cause increased phytoplankton production. This in turn may lead to increased survival of crown-of-thorns juveniles in their planktonic phase.

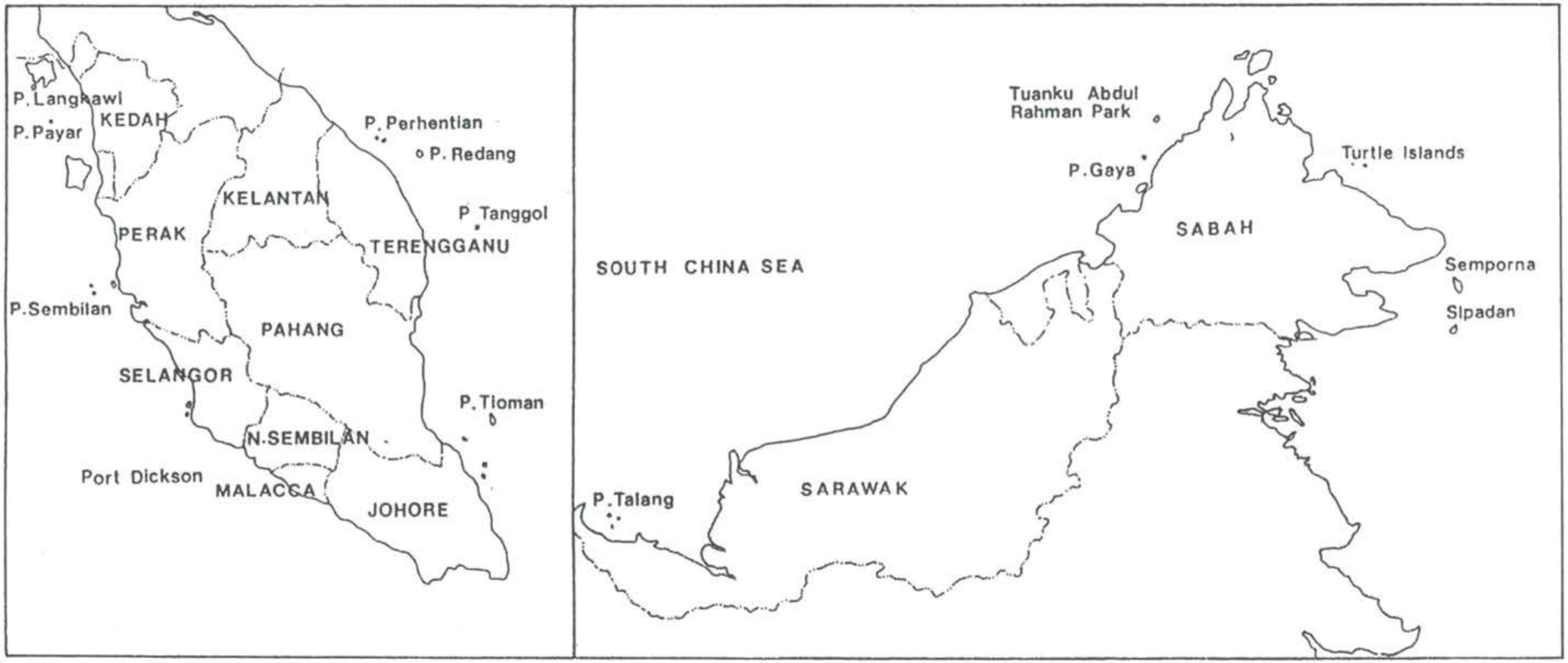
The report also notes that sewage discharge and waste disposal is still a problem on many islands. Untreated sewage is discharged directly into the marine environment on some islands. There are no regulations governing the dumping of solid wastes, and this forms a significant source of pollution, especially on islands with large populations such as Pulau Perhentian, Pulau Redang, Pulau Tioman on the east coast of Peninsular Malaysia, and Sabah in East Malaysia. See Table 1.4 for more detail.

In 1986, the Malaysian government, acknowledging the importance of protecting the coral reefs for their economic importance and aesthetic value, proposed that the marine waters around 30 islands in Peninsular Malaysia be declared as protected areas. Since then, 36 of these islands have been declared as marine protected areas and management plans for their administration have been established and implemented.

However, the state governments which have jurisdiction over the islands have not established any control regulations or measures with respect to development (construction) and pollution, or waste disposal systems on these islands. As a result, tourist resorts which have been established on these islands during the last few years continue to cause erosion and sedimentation (by construction of new facilities) and to discharge their untreated sewage into the ocean (Yaman, 1993 and Ch'ng, 1992).

Fisheries on Malaysia's reefs are of major economic and subsistence importance and a number of destructive fishing methods are used despite being illegal. Coral mining for road and building construction is now banned, and the shoreline protection afforded by reefs is now largely unaffected by this activity.

Figure 1.9 Map of major coral reefs of Malaysia.



Source: Bujang, 1995

Table 1.3 Status of some Malaysian coral reefs.

Reefs	No. of Stations	Reef Condition in Terms of:		Reference
		% Coral Cover	Visibility	
Peninsular Malaysia:				
East Coast				
Perhentian	6	56	Good	Ridzwan, 1993
Redang	9	63	Good	Mohamed and Badaruddin, 1990a
Kapas	2	42	Fair	Ridzwan, 1993
Tenggol	6	69	Good	Ridzwan, 1993
Tioman	15	27	Good	Mohamed and Badaruddin, 1990a
West Coast				
Langkawi	4	46	Poor	Mohamed and Badaruddin, 1990b
Sembilan	4	26	Fair	Mohamed and Badaruddin, 1990b
P. Dickson	4	44	Poor	Mohamed and Badaruddin, 1990b
East Malaysia Sabah	13	43	Fair	Mohamed and Badaruddin, 1990b
Sarawak	5	60	Poor	Mohamed and Badaruddin, 1990b
Oceanic				
L.-Layang	11	50	Excellent	Ridzwan *et al.* (in prep)

Percent Live Coral Cover:
75 - 100% = Excellent
50 - 74% = Good
25 - 49% = Fair
0 - 24% = Poor

Visibility:
Poor = <5m
Fair = 5 - 10m
Good = 10 - 20m
Excellent = >20m

Table 1.4 **Causes of coral reef degradation and destruction in Malaysia.**

Threats	Peninsular Malaysia		East Malaysia
	West Coast	East Coast	
Coral bleaching	1	1	1
Predation (COT)	1	4	2
Fishing intensity	3	3	5
Fishing damage	3	3	5
Boat scouring	2	3	4
Fish blasting	1	1	5
Gleaning	2	1	3
Population pressure	4	3	4
Domestic and agric. pollution	3	2	3
Industrial pollution	3	1	1
Oil spill	2	2	2
Dredging	3	1	3
Coral mining	1	1	2
Tourist activities	1	2	3
Sedimentation	5	3	4

Key to the scale values:
1 = None to rare; very low occurrence
3 = Some damage; some stress
5 = Medium to high; damaging
7 = Very high; high stress; very damaging

1.6.6 The Philippines

Lingayen Gulf in the north-west of Luzon was chosen as the study site. Coral reefs here are experiencing considerable pressure from a number of sources, including the exacerbation of problems caused by inappropriate land-use patterns, by over fishing and destructive fishing techniques. Several watersheds drain into Lingayen Gulf and these carry large amounts of tailings from upstream mines. The report suggest that there is heavy metal pollution in some sectors of the Gulf as a result of this run-off, and this pollution may be several orders of magnitude higher than recommended levels. It is noted that although some coral communities are silt adapted (e.g. near river mouths), they may not be able to tolerate the additional stress of toxic heavy metals.

The report presents an indicative ecosystem sensitivity rating and stress levels for parts of the Gulf. Present impact levels due to sedimentation are medium to high as are impact levels for various pollutants. It was also noted, however, that in the past, siltation has been demonstrated to be a major factor involved in the development of reef structure.

Studies in the Philippines have used *Acropora* and *Porites* species (in tandem) as indicators of coral reef health, and transplant studies have been carried out to test the tolerance of these species to toxic chemicals.

The Lingayen Gulf Coastal Area Management Plan incorporates the following:

- outlines of siltation and pollution management programmes;
- diagrams to elucidate ways to tackle these problems;
- the fact that the catchment area project has a need for greater coordination;
- the use of zoning as an intervention measure which has been applied to the whole Gulf; and
- ecotourism as a focus in the north-west sector.

1.6.7 Singapore

Singapore has considered all of its reefs in the inventory because no particular identifiable watershed could be associated with reef degradation.

The country has a large set of time-series of data on its coral reefs, going back to mainly qualitative information from the 1960s. The ASEAN-Australia Marine Science Project: Living Coastal Resources has provided long-term, systematic, quantitative monitoring of the reefs since the late 1980s. The overall results of these studies, which included determination of the benthic characteristics for other flora and fauna as well as corals and fish, are presented in the Singapore inventory.

The growth of Singapore, now one of the busiest ports in the world, has adversely impacted its coral reefs. These impacts can come from heavy metal pollution and oil as well as river run-off.

The reefs in Singapore's waters are mainly located around the southern islands and are thus remote from riverine discharge. The impacts on reefs from run-off is regarded as minimal. However, sedimentation resulting from land reclamation, dredging, and spoil dumping has lowered light penetration and smothered coral. The inventory states that underwater visibility has been reduced from 10 m in the 1960s to only 2 m at present. Long-term monitoring has shown a drastic reduction in live coral cover at depths below 6m. These impacts will continue as land reclamation proceeds. The upper reef slope, however, still supports healthy coral communities. Other impacts such as fishing, trade, tourism developments, and diver damage further exacerbate the overall problems.

As part of the 'Green Plan', four marine areas have been set aside for protection. These areas contain a variety of coastal habitats including coral reefs, which occupy 7 square km. An action programme of the Green Plan has been published which calls for greater protection of the reefs through better enforcement of controls and careful monitoring of the effects of reclamation projects as well as a widespread education and public awareness campaign.

1.6.8 Thailand

Thailand selected Ban Don Bay in the Gulf of Thailand as its study site. It is made up of five island groups, and the condition of the fringing coral reefs ranges from poor to good. It is estimated that 60% of the reefs are in fair to poor condition and that less than 39% of reefs are in good condition.

The major threats to the reefs come from sedimentation. Rapid infrastructure development, particularly along the beaches, as a result of a boom in tourism has caused a large increase in sediment concentration in coastal waters. This has caused high coral mortality by smothering in the fringing reefs of several island groups. Coral death by resuspended sediments from passing boats and anchor damage is also a problem in tourist areas. The abundance of reef fishes and species richness were found to be positively correlated with coral cover. Run-off from domestic, industrial, agricultural, and aquaculture sources has increased river nutrient levels, although there is no evidence of eutrophication in the Bay itself, except for some nearshore areas.

The report notes that lowered salinity in the Bay as a result of monsoon river flow has limited coral reef growth, but no suggestion is made of unnatural increases in river run-off. Solid waste pollution is a problem on some beaches. Fishing is also an important activity in the Bay, and reef damage has been associated with beam trawling, blast fishing, and fish poisoning.

The major gaps in knowledge which have been identified include the fact that there is a very poor level of understanding on workable management options among government officers, tourist operators, and local people. Although government regulations are in place to prevent blast fishing, poison fishing, coral collecting, and littering, enforcement is still a problem. The inventory states that the degradation of reefs will continue unless the following points are addressed:

- the need to raise the low public (and official) awareness of the value of coastal resources, including coral reefs;
- the lack of resources, particularly trained manpower, equipment, and boats to patrol reefs;
- the lack of coordination among government agencies, both at the local and national level;
- the need to revise outdated and confusing laws and regulations and adopt new ones;
- the need to build and maintain strong public support for management, including local participation in management; and
- the need to monitor and evaluate progress in implementing conservation initiatives, such as the National Coral Reef Strategy.

1.6.9 Vietnam

Vietnam used three main sites for the inventory. These were the Ha Long/Bai Tu Long/Cat Ba areas which lie adjacent to the Red River catchment, Nha Trang Bay, and Phu Quac Islands. These are multiple use areas for fishing, shipping, tourism, and the culture of pearl oysters. Some of the reefs have high biodiversity and productivity and have been adopted as a World Heritage Area by UNESCO.

The Ha Long/Bai Tu Long/Cat Ba area is of particular interest because it consists of over 1500 small limestone, chert, and sandstone islands, distributed fairly evenly over a distance of 20 km from the mouth of the Red River delta. Although data are not supplied, the report notes that coral cover and species diversity increase with distance from the delta - inshore reefs are now totally lost as a result of smothering by sediments. The source of sediments is unmistakable. They consist largely of black coal which originates from a large coal mine in the lower reaches of the Red River. Sediment levels in the Red River are elevated mainly as a result of mining and to a minor extent, from erosion as a result of deforestation. Oil levels are also high in the navigation channel. Despite a high population density in the delta (17 million people), there is little evidence of eutrophication in the Bay, although the report notes higher nutrient levels inshore compared to offshore. The effect of nutrients and oil on corals is not quantified as little data are available for the Vietnam reefs.

Slight eutrophication was noted in Nha Trang Bay adjacent to the Cai River catchment, but no coral degradation was noted.

Other impacts not associated with catchments are largely related to fishing practices, including blast fishing (despite a total ban), chemical poisoning (forbidden), and the side effects of trawling and harvesting of sessile reef organisms. It is noted that tourism increased rapidly after the establishment of marine parks, such as Hon Mun Marine Park, and that tourism is causing significant reef damage. Most of the damage by tourism is caused by the collection of coral for the souvenir trade (up to 70% of the damage). Other smaller marine parks have also been established, but difficulties exist in staffing them and as a result, protection is inadequate. The Ministry of Fisheries has branches in every province and among its responsibilities are the enforcement of the prohibition of destructive fishing methods. A number of reefs in the area have detailed species inventories and public environmental information.

The report notes that the revision of marine park boundaries is a compromise between practical management and adequate size for habitat protection. It also notes that there may be jurisdictional difficulties between adjacent provinces. The major management measure is to develop and implement a master plan for the sustainable use of all coral areas. This master plan will include:

- assistance for fishermen to obtain suitable equipment so that they do not use damaging fishing methods;
- development and enforcement of rules and regulations; and
- research and monitoring.

One of the results of management to date is that the occurrence of destructive fishing methods has been reduced. Revegetation of hillsides on land has also been undertaken which will reduce sedimentation and turbidity. Staff and equipment, however, are limited and enforcement of regulations is less than adequate.

Education of local fisherman with regard to the importance of coral reefs is seen as a priority. In the future, it will be important for the following to occur:

- establishment of a network of protected areas;
- education of local communities;
- adequate staffing of management agencies with responsibilities for marine national parks;
- prohibition of coral collection; and
- prohibition of damaging fishing methods.

It is also seen as necessary to:

- increase the research effort with regard to the biology, ecology, and environmental conditions of reefs;
- improvement of the social and economic aspects of reef management;
- monitoring of the recovery of damaged reefs; and
- monitoring of the threats to all sites.

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SECTION 2. SEAGRASS BEDS IN THE EAST ASIAN SEAS REGION

2.1 INTRODUCTION

2.1.1 Status of Seagrass Beds in the Region

In the East Asian Seas region, it was only in the last decade that seagrass beds were recognized as a separate and important coastal ecosystem along with coral reefs and mangroves. In Australia, the importance of seagrass meadows was considered only in the mid-1970's. Ironically, it is in these countries of the Indo-West Pacific where the world's highest and second highest seagrass species richness is found (Western Australia and the Philippines respectively, see Table 2.2). The region's seagrass ecosystem has been a focus of scientific inquiry only during the last 15 years and as an object of natural resource management, only during the last 5 years. This is because member countries of the region only very recently realized the importance of the habitat to coastal environmental protection and to their economies.

The functions and importance of seagrass beds as an ecosystem resource, collated from the submissions of the member countries of the EAS region (with the exception of Korea), are summarized below in Table 2.1. Only data supported by country studies are shown.

Table 2.1 Functions of seagrass habitats in East Asian Seas region

Country	Nursery Ground	Filter	Sediment Stabilizer	Substrate	Food[1]	Nutrient Cycling
Australia	x	x	x	x	x	x
Cambodia				x	x	
China					x	
Indonesia	x				x	
Malaysia	x				x	
Philippines	x	x			x	x
Singapore					x	
Thailand	x				x	
Vietnam	x				x	

Source: EAS-35 National Inventories, 1995

[1] Food, for dugong and turtles, although in Indonesia and the Philippines, the seeds of *Enhalus acoroides* are eaten by coastal inhabitants.

Table 2.2 **Seagrasses recorded in the East Asian Seas region.**

	AUS	CAM	CHI	IND	MAL	PHI	SIN	THA	VIE
Species	(h)	(l)	(l)	(m)	(l)	(m)	(l)	(l)	(l)
Amphibolis antarctica	x								
A. griffithii	x								
Cymodocea angustata	x								
C. rotundata	x			x	x	x	x	x	x
C. serrulata	x			x	x	x	x	x	x
Enhalus acoroides	x	x		x	x	x	x	x	x
Halodule pinifolia	x	x		x	x	x		x	x
H. uninervis	x			x	x	x	x	x	x
H. australis	x								
H. beccarii	x			x	x	x		x	
H. decipiens	x			x	x	x			
H. ovalis	x			x	x	x	x	x	x
H. ovata (= *H. minor*)	x		x		x	x	x	x	x
H. spinulosa	x			x	x	x	x		
H. tricostata	x								
Halophila sp.						x			
Heterozostera tasmanica	x								
Posidonia angustifolia	x								
P. australis	x								
P. coreacea	x								
P. denhartogii	x								
P. kirkmanii	x								
P. ostenfeldii	x								
P. robertsonae	x								
P. sinuosa	x								
Ruppia maritima					x	x		x	
Syringodium isoetifolium	x	x		x	x	x		x	x
Thalassia hemprichii	x	x		x	x	x	x	x	x
Thalassodendron ciliatum	x			x					
T. pachyrhizum	x								
Zostera capricorni	x								
Z. japonica									x
Z. mucronata	x								
Z. muelleri	x								
Total	**30**	**4**	**1?**	**12**	**13**	**15**	**8**	**11**	**10**

The letters in parentheses indicate the intensity of studies being done in each of the member countries; (h, high; m, medium; l, low)

Source: EAS-35 national Inventories, 1995.

2.1.2 Causes of Decline in Seagrass Beds

The reasons for the decline of seagrass beds in most of the countries in the region are intimately linked with economic development and a lack of marine scientific emphasis. Hence: (1) their economic importance is not fully known, thus, the orientation of local marine scientists focused almost solely on corals, seaweeds, animals, or fish; (2) the traditional orientation of the more advanced countries, those which guide the direction of the region's marine science, has viewed the ocean as a deep water mass, and it was only in the mid-1960's that the shallow benthic coastal fringe was recognized by oceanographers as a discrete ecosystem (Phillips, 1978); and (3) seagrasses exist in areas in the region that emphasize industrialization and development which has historically ignored environmental concerns (Fortes, 1995). These factors have all hampered research and understanding the importance of seagrass beds.

In the protection and use of seagrass habitats and their resources, ignorance of their ecosystem value has been a "double-edged sword". Although ignorance of the use and importance of seagrasses on the part of coastal inhabitants and policy makers is a significant factor in the habitat's "protection" (i. e., people did not disturb them too much as they were of no use), it is also a significant factor which has brought (and is bringing) about their demise and degradation. Seagrass habitats of the region are being threatened by man-induced perturbations because their value is not recognized. In addition, natural forces can add significantly to the degradation of seagrass habitats.

2.1.3 Purpose, Scope, and Limitation of the Overview

Among the ten member countries in the East Asian Seas region, only Australia, Indonesia, and the Philippines have a fairly good knowledge of their seagrass habitats and resources. Even in these countries, knowledge of the habitats' responses to environmental processes is poorly understood so that measures to mitigate negative impacts or enhance positive ones are not yet scientifically documented and available. This is particularly the case with regard to the impacts of sedimentation, nutrient-loading, and pollution (SNP). While most of the countries have initiated the formulation of or implemented their own programmes in coastal zone management when these impacts are recognized, these programmes are only at the local or national levels. They do not yet extend to the regional level where the significance is greatest; the impact is most highly felt; and knowledge most badly needed.

Most of the member countries do not yet have the required knowledge and expertise to address the issues associated with the effects of SNP on seagrass ecosystems and their resources. There is the need to collate all available information that will improve understanding of the nature and processes of seagrass beds in order to extend their benefits to stake-holders through effective research and environmentally friendly decisions and policies.

The bodies of water that connect the countries of the region consist of fairly distinct zones within which physical conditions, biological communities, fish stocks, etc. are so closely linked that they are best managed as a regional ecological unit. In addition, the concept of 'hotspots' is gaining popularity for use in selecting areas for protection. Seagrass habitats are 'hotspots' or areas rich in total numbers of species or numbers of a particular kind or category of species, especially those which are endemic, or endangered. For example, the sea cow, *Dugong dugon*, the only remaining representative of the mammalian family dungongidae, is threatened with extinction, or endangered throughout its world-wide habitat. Completely seagrass-dependent, it has been sighted in areas in the world which coincide with sites where seagrasses are in abundance (Norse, 1993; Fortes, 1989). To a similar degree, sea turtles that are also threatened with extinction are documented to feed on seagrasses, and they are also found where the plants abound.

This overview covers information available on seagrass ecosystems as they are reflected in the inventories of the member countries of the East Asian Seas Action Plan. However, some of the inventories were general in approach, giving information characterizing the entire country but not for the specific area of study. This was due to the current limited state of research on the seagrass habitats and resources. In such cases, it was incumbent upon the author to include some data and information from other sources that provide the necessary details. References to temperate seagrasses in support of statements in the text are made with the recognition that their usefulness is limited, as conditions vary greatly between temperate and tropical latitudes.

The reasons for the neglect of seagrasses in the region (discussed above) are the primary sources of the limitations of this overview. With the exception of Australia, Indonesia, and the Philippines, extremely meager information about seagrass habitats is available from the other East Asian Seas countries.

2.2 REGIONAL ASSESSMENT

2.2.1 Study Sites

The study sites in nine of the ten member countries are:

Australia	- Hinchinbrook Channel
Cambodia	- Kompong Son Bay; some islands in Kompot and Koh Kong
China	- Shen Zhen River Estuary
Indonesia	- Jakarta Bay and Seribu Islands
Malaysia	- Sungai Lukut (Port Dickson); Sungai Pulai Estuary
Philippines	- Lingayen Gulf
Singapore	- Southern Island, Labrador Beach, Changi Beach, and Tuas Beach
Thailand	- Phangnga Bay
Vietnam	- Cat Ba Islands-Ha Long Bay; Tam Giang-Cau Hai Lagoon; Truong Sa Archipelago.

These sites include: a river channel and estuary fringed with mangroves that receive inputs from a vast agro-industrial area (as in Australia, China, Malaysia); portions of bays; a gulf; islands with coastlines disturbed by coastal industrial and commercial development (Cambodia, Indonesia, the Philippines, Thailand, Vietnam); and selected sites in an area heavily subjected to impacts from coastal industrial development (Singapore). The seagrass assemblages associated with these sites are given in Table 2.3.

About 14 species are represented. Their occurrence ranges from sparsely distributed single species stands along river estuaries in China, to lush, diversified beds in coves and embayments in the Philippines. The composition of the seagrass assemblages at the other sites vary.

It can be seen from Table 2.3 that the pioneer seagrasses, *Cymodocea serrulata*, *Halodule univervis*, *H. pinifolia*, *Halophila ovalis*, and the climax species, *Enhalus acoroides* and *Thalassia hemprichii*, are the more common seagrasses occurring at the study sites. The predominance of pioneer species or climax species is a clear indication of the environmental conditions prevailing in those areas. Pioneer species suggest the prevalence of more disturbed habitats, i.e., indicating conditions too severe for other species to survive. The climax species is indicative of a more stable, relatively less disturbed habitat.

Table 2.3 **Seagrass bed composition at the study sites in East Asia**

	AUS	CAM	CHI	IND	MAL	PHI	SIN	THA	VIE
Cyrot				x	x	x	x	x	x
Cyser				x	x	x	x	x	
Enaco		x		x	x	x	x	x	
Hapin	x	x			x	x		x	x
Hauni	x			x	x	x	x		x
Habec						x			x
Hadec	x								
Hamin					x	x	x		
Haova	x		x?	x	x	x	x	x	x
Haspi					x		x		
Hatric	x								
Syiso		x		x	x	x			
Them		x		x	x	x		x	x
Zojap									x
Total	5	4	1?	7	10	10	7	6	7

Source: EAS-35 National Inventories, 1995

Cyrot, Cymodocea rotundata
Cyser, C. serrulata
Enaco, Enhalus acoroides
Hapin, Halodule pinifolia
Hauni, H. uninervis
Habec, Halophila beccarii
Hadec, H. decipiens
Hamin, Halophila minor
Haova, H. ovalis
Haspi, H. spinulosa
Hatric, H. trichostata
Syiso, Syringodium isoetifolium
Them, Thalassia hemprichii
Zojap, Zostera japonica

2.2.2 Extent/Magnitude of the Problem of SNP

The threats known to affect seagrass ecosystems and their resources in East Asia can be categorized into two major groupings: natural and anthropogenic. Natural hazards that can cause damage to seagrass beds include: floods, cyclones, volcanic materials, sediment movement, waves, freshwater outflow, and tidal exposure. It should be noted that of the two, natural causes of seagrass loss cover wider areas. Recovery from losses due to natural causes, however, is quicker compared to that resulting from anthropogenic losses. Table 2.4 presents a breakdown into specific subcategories of anthropogenic threats to seagrasses which indicates that some of these threats are inter-related.

Table 2.4 Anthropogenic threats to the seagrass beds in the East Asian Seas region

Threat	AUS	CAM	CHI	IND	MAL	PHI	SIN	THA	VIE
sedimentation	x	x	x	x		x	x	x	x
sediment smothering	x	x	x			x	x		
nutrient-loading	x		x	x		x	x	x	
sediment instability	x			x					
dredge/fill	x			x	x	x	x		
poor management		x	x	x	x	x	x	x	x
pollution	x		x	x	x	x	x	x	x
mooring scours	x				x		x		
boat scours	x				x	x	x		
bed removal		x				x	x	x	x
recreation					x	x	x	x	x
unsustainable fishing				x	x	x		x	x
coral mining						x	x	x	

Source: EAS-35 National Inventories, 1995

Among the threats reported in the country inventories, sedimentation (and its attendant effects), nutrient-loading (eutrophication), and pollution (SNP) are the most common in the region. Sedimentation has been considered both a natural and man-induced factor, being brought about largely by: river run-off (as in Australia, China, Vietnam); unusually large floods (Australia); extensive shrimp pond development (Cambodia); logging of forests and mangroves (Cambodia, the Philippines); land reclamation (China, Malaysia, Singapore); coastal development (Malaysia, Singapore, Thailand); mining (Australia, Thailand, the Philippines); and earth spoils dumping (Singapore). Studies in the Gulf of St. Vincent, South Australia (Shepherd *et al.*, 1989); Toorbul Point in Moreton Bay in Queensland (Kirkman, 1978); and in Burrum and Mary Rivers, also in Australia, (Preen *et al.*, 1993) have demonstrated that smothering of seagrass by sediment or accumulation of sediment and the consequent shallowing of the river mouth are the causes of seagrass decline. Extensive sub- and intertidal filling in Singapore; cultivation for agriculture in the Philippines; and mining in the Philippines, Thailand, and Malaysia have led to heavy siltation in estuarine areas causing burial, high water turbidity, and lower production of both seagrasses and their associated fauna (Fortes, 1989). The high sedimentation rate at the Segara Anakan-Cilacap, a highly productive lagoon in Indonesia, is expected to reduce the water body to only 40% of its present area by the year 2000 (Sujastani, 1984). The active mining firms in the Philippines produce at least 140,000 tons of mine tailings daily (EMB, 1990) which, if not properly contained, may find their way to river systems and eventually to the seagrass beds.

Poor management has been cited as a major problem that poses a threat to seagrass habitats and resources in the region. This problem arises from unsustainable practices in the watershed and the coastal waters such as: over fishing, unsound coastal development practices, and unregulated industrial, commercial, and recreational activities.

Pollution by chemical wastes is introduced into the coastal environments through discharges from industrial, commercial, and domestic establishments. These are in the form of heavy metals and toxins (as in Australia, China, Indonesia, the Philippines, Thailand, Vietnam), oils and petrogenic hydrocarbons (China, Malaysia, Singapore, Vietnam), and pesticides and fertilizers from nearby farms and fishponds (China, the Philippines, Vietnam). The most readily observable effects of pollution stress appear to be a reduction in the population size and distribution of seagrass below naturally recoverable levels. In highly polluted waters of the Mediterranean, *Posidonia oceanica* was found to accumulate the heavy metals chromium, cadmium, and nickel in its tissue, making this seagrass species a potential indicator of heavy metal pollution (Giaccone *et al.*, 1988). The root system is mainly responsible for mercury absorption and concentrations in the plant tissue seems to be correlated with concentrations in the sediments (Maserti & Ferrara, 1986). The consequences are physiological disorders of leaf tissue, growth arrest, and cellular necrosis (Cristiani *et al.*, 1980). An initial attempt in the Philippines to investigate the rate of copper uptake by seagrasses in a bay polluted by copper mine tailings found the concentration of the metal consistently double in the smaller *H. uninervis* than in the larger *E. acoroides* (Tabbu-Cruz 1989). This finding suggests correlation of copper uptake with the morphology of the species. The concentrations of copper in the plant tissues were positively correlated with those in the sediment. Detergents have been found to be lethal to seagrasses by altering the development of the plants. The basic compounds in detergents accumulate in sediments causing damage to the roots, rhizomes and leaves (Peres and Picard, 1975). Areas outside Asia with identifiable seagrass decline resulting from pollution include Chesapeake Bay (Orth and Moore, 1983), Florida (Kenworthy *et al.*, 1989), Cockburn Sound, Australia (Cambridge and McComb, 1984), and San Francisco Bay (Wyllie-Escheverria *et al.*, 1989).

Eutrophication or nutrient-loading is likewise a common threat to seagrass resources in the region. Among major pollution-related effects, the light reduction from planktonic blooms stimulated by excess nutrients is by far the greatest threat to seagrass populations. A particular problem in embayments with reduced tidal flushing is that eutrophication results from wastewater which reaches the coasts from industrial, commercial, and domestic facilities, inadequate and malfunctioning septic systems, boat discharges of human and fish wastes, and storm drain run-off carrying organic waste and fertilizers. Its direct impact creates a dramatic shift in the ecosystem's community structure and resulting decline in health of seagrasses. For these reasons, seagrass health can be an indicator of the overall environmental condition of bays and estuaries.

Human activities such as industrialization, development of recreational areas along the coasts, agricultural land uses, and dredge and fill operations are increasing in many parts of the world. Such activities have led to well documented declines of seagrass beds in both temperate and tropical areas (Maggi, 1973; Peres and Picard, 1975; Larkum, 1976). In Botany Bay, Australia, decreases in the area of seagrass beds coincided with a period of industrial and residential development in the watershed during the period 1930-1987 (Larkum and West, 1990). The increased wave amplitude brought about by dredging eroded large tracts of seagrass beds, particularly during storm events. The loss has been attributed to a history of poor catchment management, uncontrolled effluent disposal, and widespread dredging. Over the same period, *Zostera capricorni* was found to have undergone cyclical fluctuations in areas throughout the bay and had colonized many sites that were previously vegetated with *Posidonia australis*. Cambridge and McComb (1984) reported that from 1954 to 1978, the meadow area in Cockburn Sound was reduced from some 42 km^2 to 9 km^2, the loss coinciding with a period of industrial development on the shore and the consequent discharges of effluent rich in plant nutrients. In the Philippines, only about 25% of industrial firms nationwide comply with water pollution control laws. At least 31 municipalities and ten cities discharge their sewage, industrial effluent, and domestic wastes into strategic river systems and coastal areas (EMB, 1990). With an increase of this kind of pollution, there is a concomitant decrease in seagrass biomass and overall reduction in species diversity.

The effects of floods on seagrass systems are documented only in Australia, while that of freshwater outflow, only in Malaysia. In Vietnam, tidal action, which is often the dominant sediment transport mode during the dry season, can move course sediment into coastal lagoons and smother seagrass beds. Blast fishing is reportedly detrimental to the seagrass communities in the Philippines and Vietnam.

2.2.3 Management and Mitigation Measures

The documented and potential contributions of seagrasses and associated biota to the ecology and economy of coastal Southeast Asia is the most compelling justification to manage the resources on a sustainable basis. Management measures reported in the country inventories on how to address the issues concerning the seagrass habitats are closely linked with those involving management of the coastal zone in general. Measures that pertain specifically to seagrasses range from 'no or ineffective management' (Cambodia, Thailand), to some or satisfactory management' (Australia, China, Indonesia, Malaysia, the Philippines, Singapore, Vietnam).

The most common measure to mitigate impacts from SNP on seagrasses as well as other coastal habitats and resources is compliance with existing rules and regulations imposed by governments. Hence, water quality and effluent standards have been established and relevant environmental laws decreed. Monitoring programmes are being set in place and environmental impact assessments are now conducted for development projects in environmentally critical areas. Marine parks and sanctuaries have been established to protect and conserve highly threatened or vulnerable species and habitats. In order for these activities to have a positive effect in the sense of continued productivity, it is necessary to establish a stable foundation through measures of sustainable watershed management.

2.3 NEEDS

The country reports reveal significant needs to increase information and improve understanding of seagrass systems *vis-à-vis* SNP. There are needs in: the knowledge base of seagrass beds; in the management of both the resources and the impacts on these resources; and in policies to guide future research and management actions.

2.3.1 Knowledge

There is an urgent need for: (1) establishment of a database from which baseline and monitoring could be assessed to detect impacts and changes which are statistically significant and ecologically and economically important; (2) detailed quantitative baseline measures of temporal and spatial abundance, recruitment, and mortality rates of seagrass beds, and of the associated fauna and flora from which those with critical conservation status could be determined; (3) quantitative measurements of physico-chemical correlates from which pollution status could be measured; (4) studies of indicator species and responses from which monitoring organisms could be distinguished; (5) a better understanding of seagrass biology and ecology from which conservation measures could be crafted; and (6) identification of the linkages of seagrass beds with their watersheds or with wetlands and coral reefs.

2.3.2 Management

Management primarily builds upon data and information gathered through basic and applied research. Hence, for successful management of seagrass resources and the impacts from activities in the watershed and coastal environments, there is the need for: (1) baseline data to document the extent and condition of seagrass beds; (2) a monitoring programme to detect the effects of disturbance early on; (3) measures to reduce nutrient and sediment inputs; (4) proper identification of changes, causes of change, acceptable ranges of change, and critical levels of the change; (5) measures to differentiate changes due to natural and anthropogenic causes; (6) more relevant information on the economic and social values of seagrass beds; (7) active involvement of local people; (8) development or relevant rehabilitation and restoration technology; (9) capacity building; (10) commitment of both local and national governments that translates to budget provision and actions; and (11) valuation of these socioeconomic and ecological importance of the ecosystem.

2.3.3 Policy

To support research and management and at the same time get public support, there is a need for countries to review, formulate or reformulate, and strictly implement and enforce laws and policies that pertain directly to seagrass bed protection and sustainable use. Hence, there is the need for: (1) regulatory and management measures which, as in the case of environmental impact assessments prepared for dredging, consider the effects of changes in local hydrology on nearby seagrass meadows; (2) more information on the natural variability of seagrass abundance, annual trends, and impacts; (3) policies to support the use of selected meadows rather than an entire site that represent a wide range of habitats for each of the seagrass species present; (4) identification of specific responsibilities in implementing and enforcing rules and regulations; (5) guidelines and policies governing the conservation of seagrasses; and (6) development of financial schemes that would sustain the various management and scientific activities.

2.4 CONCLUSIONS

While member countries have exerted exceptional efforts to address the issues confronting the actual and potential decline of seagrass habitats due to SNP, there is a dearth of research that gives the required information for their management, protection, and impact mitigation. Where management and mitigation measures are in place, however, these are largely ineffective or, in some cases, socially inappropriate. All countries recognize the urgent and immediate need to manage and protect these resource due to the well documented importance of the habitats in the stabilization and protection of coasts and in the maintenance of highly productive coastal ecosystems on which the economic well-being of coastal communities, especially in the less developed member countries of the region, are dependent.

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SECTION 3. COASTAL WETLANDS IN THE EAST ASIAN SEAS REGION

3.1 INTRODUCTION

3.1.1 Status of Coastal Wetlands in the Region

There is a wide variety of coastal wetlands in Southeast and East Asia. The data available from the country reports make any summation or generalization difficult. In addition, some coastal wetlands now in existence are secondary in nature. In Java and Singapore, for example, many of the existing, more open-country type coastal wetlands were previously occupied by mangroves and/or peat-swamps, and their current status belies their original condition.

For practical purposes, we recognize two main categories of coastal wetlands - forested and open. Forested coastal wetlands are those which have trees and a forest canopy (e.g., mangroves and peat swamps), including mudflats associated with them. Open coastal wetlands are those which do not have high vegetation or trees (*e.g.*, tidal marshes, non-mangrove associated mudflats, and deltas). In addition, two further sub-categories should be recognized - primary and secondary. Primary coastal wetlands are those which contain mostly original vegetation, substrate, and/or retain an unaltered ecosystem. Secondary coastal wetlands are those which have been altered by man substantially, so much so that the original vegetation and ecosystem has changed. In many cases, wetlands intergrade from secondary to primary. It is also important to differentiate between supralittoral, littoral, and sublittoral habitats. The main primary coastal wetlands considered in this report (mangrove swamps, salt marshes cum mudflats, tidal marshes, and delta), are all basically littoral in nature, although mangroves have a substantial supralittoral component. In addition, coastal peat swamps are regarded as coastal wetlands, but although this ecosystem may be influenced by tides to some degree, the waters in this habitat are essentially fresh and the habitat is regarded as non-marine. It is also relevant to comment that the sublittoral, shallow-water benthic ecosystems adjacent to the above habitats are also essentially part of the coastal habitat. For practical as well as management purposes, however, these will not be considered in this presentation. There are also primary supralittoral coastal but non-wetland habitats which are rarely considered in most studies; for example, the various kinds of beach habitats (cliff, rocky, and sandy). These habitats, however, have generally depauperate vegetation and macrofaunal diversity.

Coastal wetlands are pivotal in any integrated management scheme for wetlands. They sit at the mouth of all major rivers and watersheds, and most of them are adjacent to key sublittoral habitats like reefs and seagrass beds. Coastal wetlands are influenced by both freshwater and marine factors, and because of their position, are also the first areas lost to reclamation and conversion. The fact that most major ports and cities sit at the mouths of large rivers compounds the problem.

3.1.2 Purpose of Overview

The overview is necessary to identify the key causes of coastal habitat degradation in Southeast and East Asian Seas. The causes of the loss of such wetlands is very diverse, and it is important to consider each of the more serious ones in order for effective management and/or mitigation measures to be developed. It is also relevant and important to consider the major threats for each kind of habitat and each country.

Due to the complexity of the habitats and problems involved, the underlying philosophy of management of the sediment, nutrient-loading, and pollution (SNP) of the various habitats must follow the precautionary principle. It is unrealistic to set target levels of sediment, nutrient, and pollution loads which are "safe" for these habitats, because each area differs so much from another.

3.1.3 Factors Attributed to Degradation

The main causes of coastal wetland habitat degradation can be summarized as follows:

a. **Reclamation and conversion** - Reclamation and conversion of coastal wetlands includes land clearance for industrial and housing developments, aquacultural and agricultural ventures, tourist resorts, beach improvement, sand-mining, and waste disposal.

These developments have the significant short-term effect of substantially increasing down-current sediment loads (*e.g.*, through erosion), and increasing the nutrient and pollution loads as a result of releasing the loads previously "locked up" in the intact ecosystem. These increased load fluxes will have primary and secondary effects. As a primary effect, they will stress the adjacent areas of the affected habitat (*e.g.*, decrease fisheries, cause fish-kills, smothering of smaller plants and animals). The secondary effect of these developments would be that these loads will stress sublittoral habitats (*e.g.*, reefs, seagrass beds and other benthic communities).

The long-term effects (if un- or mismanaged) are continued increases in siltation and sediment loads (because of erosion), nutrient loads (*e.g.*, from untreated sewage and fresh water discharges), and toxic chemical loads (*e.g.*, from the use of pesticides and herbicides).

It is also very important to note that all developments which involve removal of primary vegetation and conversion of substrates will have serious secondary effects on the coastline. Once the primary wetlands are lost, erosion due to riverine currents, tidal-action, wave-action, monsoons, and typhoons will increase, and this will automatically result in further increases in silt and sediment loads. Secondary coastal wetlands are invariably more vulnerable to erosion and scarring than primary ones.

The reclamation and conversion of coastal wetlands, especially mangroves, for aquaculture is identified as a serious threat, and the long-term viability of many such ventures remains to be demonstrated (*e.g.*, in Indonesia). Even when viable, they pose problems. For example, shrimp farms cause serious short-term disruptive events, *i.e.*, water acidification due to release of sulphides/sulphates (when ponds are being dug or repaired), discharge of sediments (during construction and during post-harvest clean-ups), discharge of toxic chemicals (*e.g.*, pesticides used to "sterilize" ponds prior to stocking), discharge of antibiotics and other chemicals used to control diseases.

Many coastal peat swamps, have also been converted for aquaculture (*e.g.*, for fish farms), agriculture (*e.g.*, for padi), and transmigration in Malaysia and Indonesia. The primary and secondary effects of developing these wetlands are very similar to those encountered for mangrove swamps. In addition, the loss of coastal peat swamps has serious hydrological consequences, especially in the management and control of floods during periods of heavy rain and high tides. Such swamps create a "sponge" effect and have been shown to be very important in preventing flood devastation.

For both mangroves and peat swamps, the loss of these wetlands will result in riverine waters flowing faster and more directly to the open sea. This will mean that not only are the river-carried residual sediment loads from upstream not filtered out by these wetlands, but the faster flowing waters will cause more erosion and further increase the sediment load. The resulting associated floods and the increased tidal wave-action (normal as well as that caused by monsoons and typhoons) only aggravate this problem.

The long- and short-term sediment and nutrient discharges will have a serious impact on reefs and seagrasses, adding to the loads already coming in from distant riverine sources. In any case, all these problems are secondary to the main threat of losing these species-diverse wetlands in the first place and the associated loss of stenotopic species.

A secondary factor to consider in coastal wetlands where water flow is more restricted (*e.g.*, Straits of Johore) or in lagoons is that developments (like bunds, dams, fish-farms, bridges *etc.*) can severely affect the water flow. This results in slow dispersal of sediment, nutrient, and pollution loads with aggregation and/or concentration of these loads to fatal levels.

b. **Uncontrolled harvesting** - The uncontrolled harvesting of coastal forest resources *e.g.*, unrestrained and over-exploitation of mangrove wood for poles, firewood, construction purposes, and charcoal will undoubtedly convert primary coastal wetlands to secondary ones. This results in extensive clearing and degradation of the mangrove habitat. The same is true of indiscriminate logging (and its associated activities) in peat swamps which destroys the habitat. Overfishing is also a serious threat as it depletes coastal resources beyond the point of quick recovery. This is an especially serious problem in areas which border major cities.

c. **Forestry conversion (silviculture)** - Many mangrove areas have been converted to monoculture stands (especially of *Rhizophora*) to support local construction and charcoal industries. In essence, the primary heterogeneous mangrove system has been converted to a secondary homogeneous system, with a concurrent loss of diversity. These secondary wetlands probably do not pose such serious problems to downstream erosion and siltation as do completely degraded wetlands, but whether the secondary system's ability to filter nutrient and pollution loads is as good as that of a primary one remains poorly studied.

d. **Hydrocarbon discharges** - This is identified as a major potential threat to the coastal wetlands; *e.g.*, along both sides of the Straits of Malacca. This waterway is a major shipping artery, and there are invariably small but regular illegal discharges of oil which end up polluting both the coastal peat swamps and mangroves of Sumatra and Malaysia. These hydrocarbon discharges affect the quality of local fisheries (especially of shellfish), and the most serious effect is that many of these pollutants are locked up in the soft substrates of mangroves for many years. The spills which have occurred in the past invariably have caused only localized damage and the system has in all cases, recovered within 5-10 years. This rapid recovery is probably partly due to the resilient structure of an intact primary mangrove wetland and because the adjacent, non-polluted areas remain healthy, allowing for rapid recruitment and recovery of the affected species.

e. **Heavy metal and chemical pollution** - These pollutants are especially serious in wetlands near city areas or where rivers serve major population or industrial areas. The few correlatory studies done thus far suggest that when these loads are very heavy, the quality of the sublittoral waters is seriously affected with a concurrent loss of diversity and reduction in fisheries. In almost every case, the coastal habitat has already been completely degraded, cleared, or developed. This makes it difficult to assess the impact of these pollutants on intact primary coastal wetlands. In areas where such pollutants flow into more or less intact primary coastal wetlands, the effects have not been well studied, although local fisheries (*e.g.*, for shellfish) are affected as these seafoods cannot be sold due to high heavy metal content.

f. **Sewage pollution** - This is a serious problem identified for coastal wetlands near and/or downstream of major human habitations. This form of pollution has serious implications for local fisheries (*e.g.*, shellfish with high coliform bacterial counts cannot be sold) and ecotourism.

g. **Mining activities** - These activities are very serious in several watersheds in which there are extensive mining operations (*e.g.*, parts of the Philippines). Very heavy silt loads (often with associated heavy metal loads) enter rivers and smother coastal habitats. The high sediment loads also have very serious effects on the watershed's drainage itself.

h. **Maintenance activities** - In areas where deep waters are needed for shipping, dredging is regularly done. Dredging is a major cause of siltation and water turbidity, as it continuously stirs the sediment bed resuspending sediments, which are carried into wetland areas by wind and tidal action.

i. **Trawling** - Inshore trawling is banned in many countries but is still prevalent in some. Inshore trawling is a very destructive activity, not only to the ecosystem itself, but also to the fisheries stocks and can cause high water turbidity.

j. **Upstream influences** - Upstream activities like deforestation, industrial and housing developments, mining, dams, and irrigation works all affect coastal wetlands, although the effects have been poorly documented in Southeast Asia. Deforestation and development projects upstream will substantially increase downstream sediment, nutrient, and pollutant loads, which will stress closed forest coastal wetlands like mangroves and open coastal wetlands like mud-flats and estuaries. In addition, mine tailings and discharges from agricultural (*e.g.*, oil palm and rubber) factories are often untreated and toxic.

It has been shown that uncontrolled and/or excessive damming and irrigation activities will reduce water volume to coastal wetlands which will seriously affect the structure and integrity of mangroves and, especially peat swamps, causing dehydration and long-term hyper-salinization of the substrate. The loss of sufficient water flowing downstream because of irrigation or dams will also cause a drop in coastal ground waters resulting in seawater seeping inland (salt intrusion) and causing coastal soils to become salinized. This has very serious consequences for agriculture and aquaculture. Damming activities also shut off the normal sediment loads reaching mangroves, which will affect their integrity and health. Intensive agricultural activities will result in substantial run-offs of chemical pollutants like pesticides and herbicides as well as nutrients. This causes eutrophication of the coastal wetlands, with open estuarine areas being especially prone to algal blooms.

3.2 REGIONAL ASSESSMENT

3.2.1 Extent and Magnitude of Problem

The loss of coastal wetlands, especially mangroves, has been dramatic. Malaysia, Thailand, Indonesia, Singapore, Cambodia, and Vietnam contain about 35% of the world's mangroves (covering some 56,000 square kilometres). Even more important is the fact that these are also the world's most complex and diverse kinds of mangrove wetlands, with the highest species diversity, not only in animals but also in trees. The ecology of Southeast Asian mangroves has been studied in detail for several decades, but because of the size and complexity of this habitat, much remains to be discovered. About 30-40% of the mangroves in Malaysia, Thailand, Indonesia, Singapore, and Cambodia have already been lost.

Coastal peat swamps used to be very extensive in Malaysia, western Indonesia, and southern Thailand, but most are now severely stressed. This habitat has been very poorly studied and is generally regarded as "unproductive land". The ecology and biodiversity of peat swamps has only been studied in detail over the last 10 years. The losses in acreage of peat swamps are not well documented, but nevertheless very high - in Malaysia, some 50% have been lost. In Indonesia, there are no clear figures (they are believed to be very high as well), but almost all such wetlands in Java have been cleared, and those in Sumatra are now being cleared at a very rapid rate. The regional loss is estimated at between 35-40%.

Salt marshes, mud-flats, tidal marshes, and deltas are more characteristic of temperate areas, where estuarine areas and/or areas near river mouths have aggregated mud and silt deposits without the associated dense vegetation. These wetlands are very important for shellfish and other marine products as well as being the feeding grounds for many animals (*e.g.*, birds). In cases when such habitats border major towns or ports, levels of siltation and pollution can be very high, often leading to serious stress or the near-collapse of the ecosystem.

The available data from all countries suggest that most coastal wetlands are not seriously affected by high short-term sediment, nutrient, and pollutant loads. Coastal wetlands, especially mangroves and peat swamps, because of the depth and complexity of the habitat, soft and deep substrates, seem to have a sponge effect, effectively "locking" up man-induced sediment, nutrient, and pollutant loads for long periods without ill-effect (i.e. as a *de facto* sediment trap). Open-country and less complex coastal wetlands like salt marshes, mud-flats, tidal marshes and deltas, however, are more seriously affected, with the resident fauna being smothered and/or destroying local fisheries.

In the long-term, however, anthropogenic loads can smother or contaminate even mangroves and peat swamps, gradually destroying these wetlands. This will undoubtedly affect the fisheries in the mangroves as it might affect fish, crustacean, and shellfish populations (*e.g.*, through smothering and algal red-tide blooms), reproduction, and recruitment.

An important aspect to consider is that, while most coastal habitats are apparently very resilient to sediment, nutrient, and pollution loads, this applies only for the short-term, and only for mature, forested coastal systems. In the Philippines, it has been shown that reforestation efforts have been seriously hampered by heavy sediment loads which smother and kill saplings. Heavy sediment loads probably also affect recruitment rates of intact coastal habitats, and the long term effects of high nutrients and pollutant levels on the health of mangrove organisms, their reproductive rate, behaviour etc. is very poorly known. The use of physico-chemical data alone is not sufficient as it is not sensitive enough to indicate negative effects on the coastal habitat over the long-term. Gaining supporting evidence through the use of bioindicators is critical. Such bioindicators (*e.g.*, detritivores or filter-feeders) can indicate if a system is under stress as a result of high sediment, nutrient, or pollution loads, and the data can be of a quantitative nature if they have been obtained correctly. There is thus a need to identify suitable bioindicators for each study site, and there is an urgent need in this matter for national and regional cooperation between agencies and institutions.

One of the targets of the project was to establish a quantitative correlation between factors causing degradation. Reclamation and conversion projects tend to start a very vicious cycle of habitat destruction which results in very rapid degradation. As coastal forests are cleared for reclamation and conversion, and towns (and facilities) spring up, more people congregate around these areas, population increases through immigration. Hence, more local people take to fishing, both as a job and to help feed a burgeoning population which places greater pressure on the resources in an area. Overfishing and over harvesting of resources result in the break down of the ecosystem. Simultaneously, this influx of people results in more coastal land being cleared for housing. At the same time, organic and inorganic wastes are generated, most of which enter the coastal waters untreated. Nutrient and pollutant loads increase. As land is indiscriminately cleared, erosion and sediment loads increase. This negative catalytic effect of reclamation and conversion is a very serious problem which has been identified but is difficult to deal with. It helps explain why coastal areas under development are degraded so rapidly and also emphasizes the need for planning management to be multi-dimensional and multi-sectorial.

3.2.2 Management and Mitigation Measures

The role of mangroves and swamps as eco-filters is a matter which should be seriously considered as the effects of land-based discharges on reefs and seagrasses will be lessened if these wetlands are not degraded. The long-term effects of pollution of coastal wetlands by industrial chemicals is unknown, but a large amount of pollutants are undoubtedly trapped in the sediments in the soft substrates of these areas. The negative effects on fisheries resources is clear; fish, crustacean, and shellfish populations will be severely affected over both long- and short-terms, which can have drastic socio-economic repercussions.

The only management option is that any coastal reclamation and conversion project should take into serious consideration the long-term negative consequences as already discussed. Terms of reference for all environmental impact assessments conducted before such developments must take into consideration all the above effects. When development has to occur, it is important to ensure that sufficient tracts of these coastal wetlands (especially along the wave-front) are conserved, not only for biodiversity reasons, but also to minimize erosion and leaching. Economic valuation of any coastal reclamation and conversion project must balance the direct economic gains of the development with the indirect effects on fisheries and ecotourism in adjacent ecosystems.

Coastal habitat reforestation is one remedy, but is practiced only in the Philippines and Thailand to any extent. Even then, it is still on a relatively small scale due to the costs involved. As a management option, it is relatively expensive and may not be cost-effective. In parts of the Philippines and Thailand, some reforestation programmes have been local successes. There are problems, however. In the Philippines, programmes to rehabilitate ex-mangrove forests through reforestation and conservation have run into difficulties because of land ownership issues. All too often, in many countries, land is viewed purely as an investment resource (*i.e.*, to be used as collateral or for speculation), and large tracts of coastal habitat are thus destroyed without real economic gain to the local population. While some community-based management plans (especially for mangroves) exist, these are on a relatively small scale. Various countries however (*e.g.*, the Philippines and Indonesia) have a clear government mandate to rehabilitate areas which have been lost to aquaculture, silviculture, or failed development projects. Rarely, the bulk of the costs for such rehabilitation programmes are borne by the developers as required by local law.

Treatment of all discharges from all housing areas, factories, and plants is necessary to ensure that sediment, nutrient, and pollution loads do not reach dangerous levels. This is necessary because it is not possible (not realistic at least) to expect different areas to co-ordinate their untreated discharges so that the overall discharge from the drainage area is at the "safe level". Mine tailings are a serious problem. Sediment traps must be built and the water treated before release to reduce the sediment and heavy metal content. Sediment traps should also be a standard feature of all construction projects, including those in or near coastal areas. Controls for irrigation water, the number and position of dams built, sewage treatment, and restriction on chemicals used for agriculture and aquaculture must also be built in.

With regard to legislation, country inventories indicate that almost all countries have laws and regulations which could help conserve coastal wetlands and ensure that sediment, nutrient, and pollution loads flowing downstream to and from coastal areas are within safe limits. The problem is that while such legislation and guidelines exist, their implementation and co-ordination is lacking. In several cases, "inland" and coastal management come under separate government bodies, which represent very different interests. Enforcement is also clearly a serious shortcoming. This is the result of many factors, not the least being a lack of manpower and funds. As a result, even protected areas are being degraded. Clearly, each country needs an integrated, multi-sectoral approach to the management of wetlands in order to ensure that all the needs and problems are addressed.

3.3 NEEDS

3.3.1 Knowledge

There are presently gaps in knowledge that are important for management of coastal wetlands and for mitigation measures for combating adverse effects. These are of two general types, one technical, the other procedural.

There is a need to increase technical knowledge with regard to how useful coastal wetlands care. Other than limited data from countries like Malaysia, most citations of why mangroves are important to fisheries, etc., are anecdotal or unsubstantiated by figures or proper studies. Such data, when obtained, will then need to be subjected to economic valuation to determine the total, long-term value of wetlands. Also much of the data on sedimentation and pollutant levels (when available) are lumped data; without any indication of what the components are, where they might have originated, or any temporal considerations. Also missing are data for sediment and pollutant loads during periods when coastal wetlands are removed or cleared. Another serious shortcoming is the absence of a standard set of guidelines as to what levels of sediment, nutrient, or pollutant loads are "serious". It seems logical that the various project participants adopt a regional set of guidelines (with standardized terms and units of reference) for what can be regarded as dangerous sediment, nutrient, or pollutant loads (as a minimal figure or range) which may be modified slightly for each country's specific needs. This will allow at least some measure of comparison and help less developed countries in establishing guidelines for themselves.

3.3.2 Management

The most serious procedural shortcoming in management is the very diverse forms of data-gathering practised by the various countries, providing almost no basis for effective comparison. Data sets for the Republic of Korea are extremely detailed, but not comparable with other countries which only tests specific components without indication of what methods have been used, how data were gathered, time frames, analyses utilised, or linked factors which may affect the results.

The absence of reliable and comparable quantitative data overall is a problem and attempts must be made to rectify this. Most country reports merely present qualitative information with some quantitative data, and this makes determination of management options difficult. This is a very serious shortcoming of environmental and management planning in this region. There is a clear absence of monitoring data, except for a few sites, and as such, long-term impacts cannot be established. The lack of clear baseline data to which current data can be compared makes quantitative assessment very difficult and unreliable. The absence of data on socio-cultural-economic factors (which is a very important aspect for many developing countries) in many cases also compounds the data usage difficulty. In light of this, the adoption of the precautionary principle is a logical and sensible position until clear data is available.

3.3.3 Policy

In most countries, there were many different levels of management. There were bodies for the management of specific species resources (*e.g.*, fisheries or forestry) and often separate ones for species or specific habitat conservation (*e.g.*, wildlife or conservation). Sediment, nutrient, and pollution loads were managed by environmental or pollution departments; whilst coastal lands were often under one or several organizations. The multitude of government bodies responsible for controlling SNP emissions and habitat management makes any integrated management plan very complicated indeed. However, this project provides clear indication of the importance of integrated management of watersheds and related coastal and marine areas. This approach acts to safeguard natural resources providing socio-economic benefits, biodiversity, and sustainability.

3.4 CONCLUSION

The threats to coastal wetland ecosystems have been well argued and examined by many studies. One of the main findings of this project is that the effects of sediment, nutrient, and pollution loading on coastal wetlands appear to be of secondary importance. Land reclamation and conversion of these wetlands are the major threats confronting this habitat. The degradation of coastal wetlands represents a major source of detrimental sediment, nutrient, and pollution loads into sublittoral marine wetlands like seagrass beds and reefs. The total loss or conversion of coastal wetlands will substantially increase these loads over the long term, both through direct erosion and leaching. This aspect must be considered very seriously before any coastal area is developed or lost.

3.5 RECOMMENDATIONS

1. The kinds of sediments, nutrients, and pollutants must be clearly defined and the protocol for their detection determined. This protocol must take into consideration spatial and temporal factors as well as standardized sampling methods. Each data set should be accompanied by maps, and, as far as possible, associated data such as geography, hydrology, soil type, and vegetation should also be included.

2. The importance of bioindicators in indicating the long term negative effects of high sediment, nutrient, and pollution loads is identified (see RCU/EAS Technical Reports Series No. 7 and No. 8). The advantage of bioindicators over standard physico-chemical procedures is that bioindicators are both more sensitive and easier to utilize (both cost and ease of use).

3. The impact of coastal habitat reclamation and conversion/degradation on associated coastal ecosystems like reefs and seagrass beds must be emphasized. These wetlands are a serious source of sediment, nutrient, and pollution loads when degraded. This impact must be studied in greater detail. The role of coastal wetlands as buffers or sponges must also be examined in greater detail.

3.6 COUNTRY SYNOPSES

3.6.1 Australia

The major wetland selected is situated in the Herbert River Delta which includes the Hinchinbrook Channel and the Missionary Bay at the northern end of Hinchinbrook Island with a total area of mangroves: 13,920 ha.

Uses of coastal wetlands

- Aquaculture
- Tourist resort
- Commercial development

Threats from development

- Damage to or loss of mangroves
- Discharge of sewage, pond effluent, and other wastes
- Engineering activities associated with the construction of marinas, dredging, and cutting channels through mangroves and seagrass areas to provide ocean access.

Long- and short-term impacts of threats

The mangroves of the delta are protected as a fisheries habitat by state law. Long-term impacts as a result of human activities are the clearing of mangroves for aquaculture enterprises, coastal resorts, and other coastal development.

Management practices (in place or planned)

The mangroves of the delta are protected by state law as a fisheries habitat.

3.6.2 Cambodia

The major wetland selected is situated in the Prek Kompong Bay Estuary in Kompot Province. The Prek Kompong Bay Estuary is the rightward flow of Prek Kompot between Koh Daung and Phnom Bokor. Mangroves are generally scarce along the river. Mangroves grow well in the estuary with a total mangrove area: 37,000 ha.

Uses of coastal wetlands

- Clearance of mangroves for salt field expansion
- Harvesting of seafood
- Cutting of mangroves for firewood and fishing material

Threats from development, long- and short-term impacts

Destruction of mangroves along the coast for the extraction of firewood and salt field expansion will lead to serious deterioration of the marine and coastal environment. Sedimentation is likely to affect the coast in the long term due to upstream deforestation and the cutting of tidal mangroves. Many other types of vegetation are also being cut, both along the river and in the estuary area.

Nutrient and pollutant loads are believed to be high and affect the water quality of the estuary although no data are available. More than 500 families living on the river banks dispose of their domestic waste directly into the water. Some small scale industries also discharge their untreated waste directly into the waters.

Management practices (in place or planned)

No practical conservation measures have been taken. There is an urgent need to develop management plans, master plans, zoning, mapping, and inventory for the wetland areas. All development and fishing activities should be strictly controlled. Nonetheless, some initiatives towards the conservation and protection of nature have been or are being implemented:

- Royal decree of 1 November 1993 on "Designation of protected areas system" signed by the Ministry of Environment (in 1994). See Figure 3.1 for detail.
- Identification of sites for shrimp culture along the coast by Ministry of Environment (MOE) staff in cooperation with staff from Ministry of Agriculture (MOA) (in late 1995).
- Master plan for Cambodian coast adopted by Asian Development Bank (in late 1995).
- National Wetland Action Plan to be formulated by the Cambodian National Wetland committee.

Assessment of coastal wetlands (Report card)

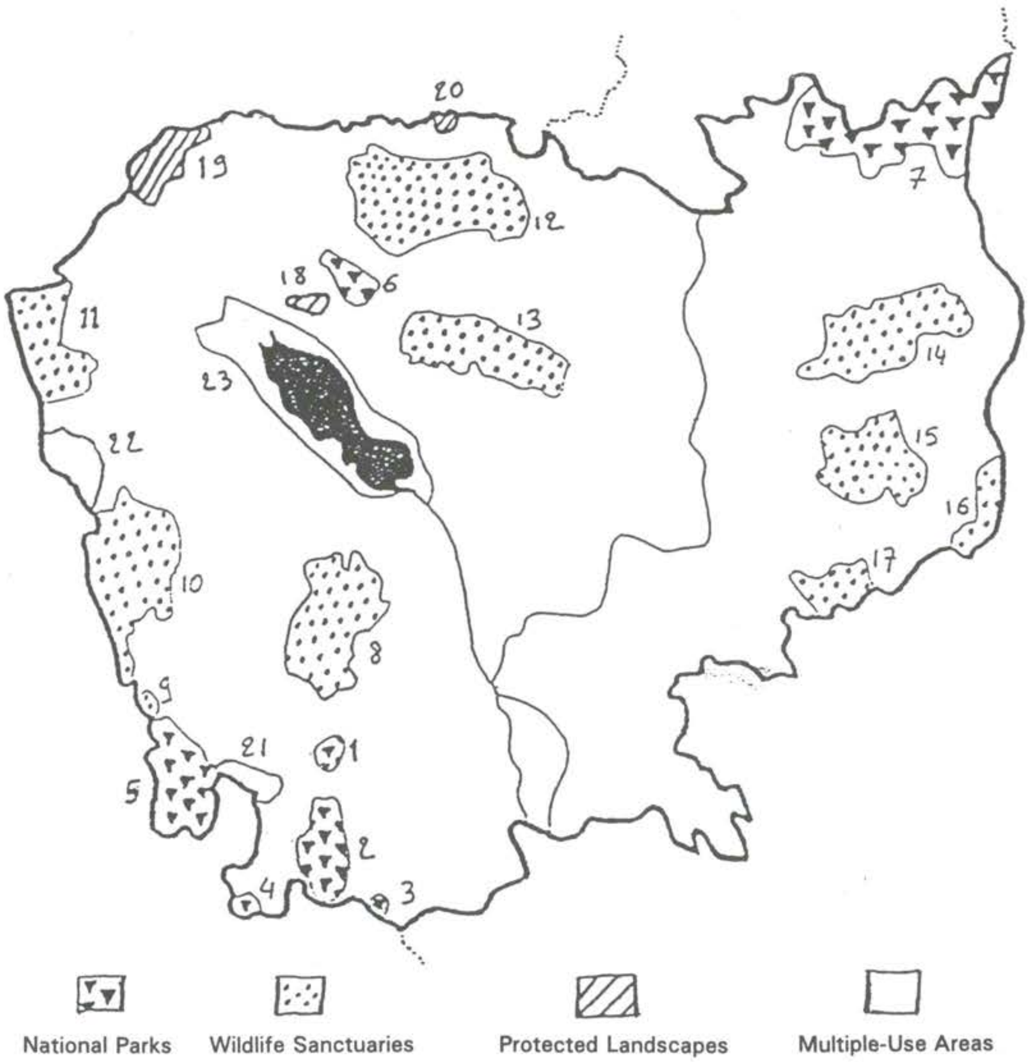
Data are not available for sediment, nutrient, and toxic chemical loads due to the lack of equipment and laboratories, experience and skill in conducting such research work. All the factors listed below are believed to be at a critical level.

- Sedimentation: Considered heavy due to clearing of the adjacent areas for salt field expansion and for agricultural purposes. Deforestation upstream and clearing of mangroves compound the problem.

- Nutrients: Probably exist due to numerous human settlements and livestock along the river.

- Pollutants: Mainly oil spills, domestic waste, and manufacturing waste from small scale industries as a result of uncontrolled waste disposal.

Figure 3.1 Designation of protected area created by Royal Decree 1 November 1993 in Kingdom of Cambodia



Source: Neath, 1995

Reference:

National Parks
1. Kirirom (35,000) 2. Phnom Bokor (140,000) 3. Kep (5,000)
4. Ream (15,000) 5. Botum Sakor (171,250) 6. Phnom Kulen (37,500)
7. Virachey (332,500)

Wildlife Sanctuaries
8. Phnom Aural (253,750) 9. Peam Krasob (23,750) 10. Phnom Samkos (333,750)
11. Roneam Daunsam (178,750) 12. Kulen Promptem (402,500) 13. Boeung Per (242,500)
14. Lomphat (250,000) 15. *Phnom Prich (222,500)* 16. *Phnom Nam Lyr (47,500)*
17. Snoul (75,000)

Protected Landscapes
18. Angkor (10,800) 19. Banteay Chhmar (81,200) 20. Preah Vihear (5,000)

Multiple-Use Areas
21. Dong Peng (27,700) 22. Samlaut (60,000) 23. Tonle Sap (316,250)

Source: Royal Decree, "Creation and Designation of Protected Areas", 1 November 1993

Report card assessment of coastal wetlands

Categories	Mangroves	Mudflats, Sandflats	Seagrasses	Coral Reefs
State of knowledge on ecology	just sufficient	satisfactory	satisfactory	just sufficient
Nature of disturbance: Extent?	severe disturbance	some disturbance	severe disturbance	severe disturbance
Management options: Existing?	no management	negligible management	negligible management	no management
Management effectiveness: Effective?	ineffective	just sufficient	ineffective	ineffective

Impact of wetland on reefs and seagrass bed

Destruction of mangroves has affected the seagrass and coral reef populations. Seagrasses in Kampot Province have been and are continually being destroyed by extensive fishing activities. Coral reefs are subjected to extensive exploitation for trade related use with exports mainly to Thailand.

3.6.3 China

The major wetland selected is situated in the Pearl River, which is the second largest river in China in terms of annual discharge. It is recommended as a case study of integrated management of watershed due to the area's rapid economic and urban development taking place and its long coast line which affects a large marine area.

Uses of coastal wetlands

- Agriculture
- Urban housing
- Location for industries

Threats from development

- Sources of pollution:

  - Point source: industrial and domestic waste water
  - Agricultural farmland: source of nutrient and toxic chemicals
  - Non-point source: soil erosion
  - Ships

Water quality

Water quality varies spatially. Water quality problems are mostly caused by concentrations of COD, NH_4-H, and phenols which exceed regulatory limits. Concentration of NO_3-N and suspended solids have slightly increased, but concentrations of toxic chemicals have decreased by half.

Long- and short-term impacts of threats

- Soil erosion as a result of large scale development is causing water in the river to become turbid. This turbidity causes the coastal wetlands to increase in area which speeds up reclamation of the wetlands. Soil erosion causes sedimentation which narrows the waterways and increases the flow velocity. Consequently, turbid waters are pushed further out into the marine areas.

- Urbanization is damaging coastal wetlands with a decrease in bird species and numbers.

- Pollution by organic materials and nutrients is reducing populations of some endangered fish species. Nutrient levels and eutrophication are increasing. Red tides have been reported 39 times between 1980 to 1991. The exact proportion of the various pollution sources to the river is not known.

- Oil pollution comes from watercraft and part from the discharge of industrial wastewater. There is no estimate available of how much oil is being discharged into the Pearl River.

- Toxic chemicals and heavy metals are not pronounced in the Pearl River watershed and related marine environment, but some toxic chemicals are the residuals of banned pesticides and insecticides. Some heavy metals are from mining. Industrial sources of toxic chemicals and heavy metals are not clear.

Management practices (in place or planned)

There are several major laws, regulations, and counter measures for environmental protection in the People's Republic of China (PRC):

- The Marine Environmental Protection Law of the PRC adopted on August 23, 1982, is intended to protect marine environmental resources from pollution. It also strives to maintain the ecological balance to safeguard human health and to promote the development of marine programmes.

- The Regulations Concerning the Prevention of Polluting Sea Areas by Vessels of the PRC, promulgated on December 29, 1983, and the Regulation of the PRC Concerning Environment Protection in Offshore Oil Exploration and Exploitation, enacted on December 12, 1983, are to prevent pollution to the marine environment by offshore oil exploration and exploitation.

- Regulation of the PRC Concerning the Dumping of Wastes at Sea, promulgated on March 6, 1985, strictly prohibits the dumping of wastes at sea.

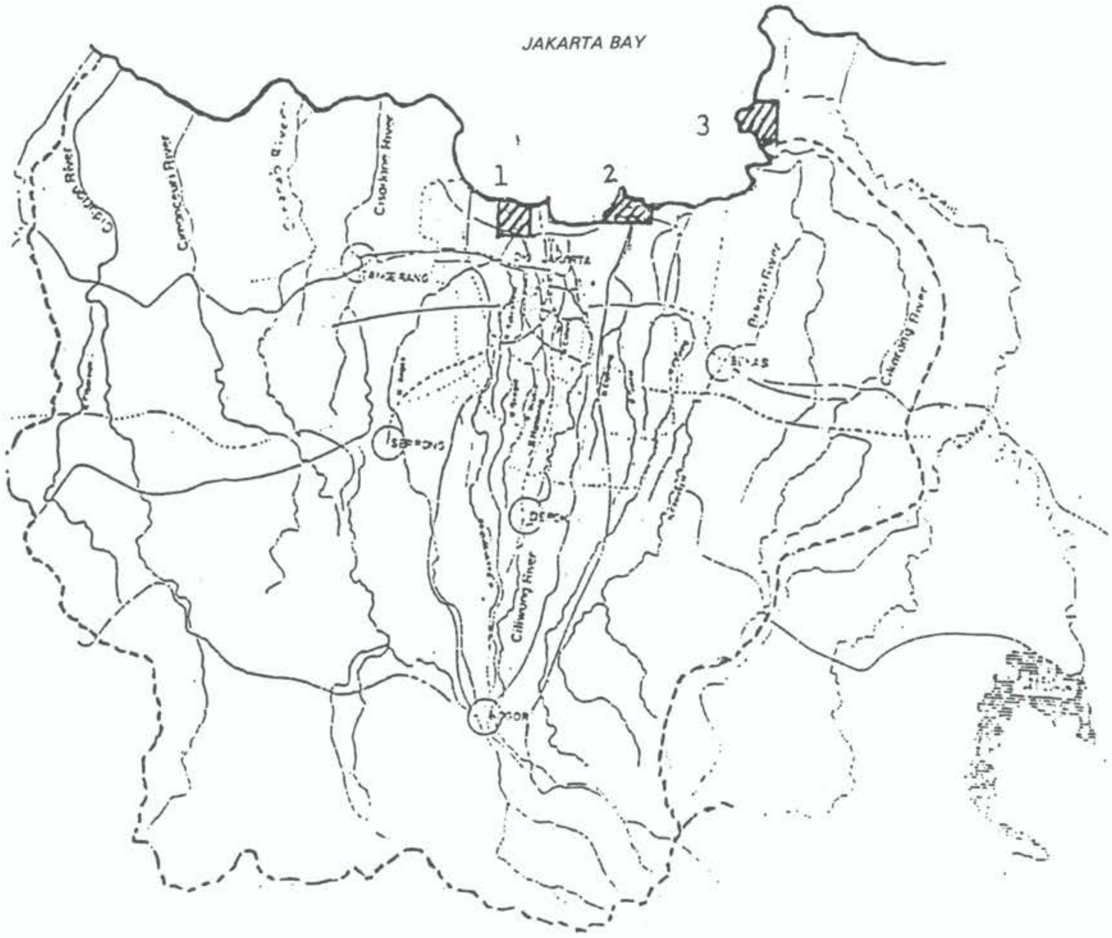
- The Management Guidelines on Environmental Protection at Construction Projects of the PRC issued in March, 1986 strengthens the management of the environmental impact assessment of construction projects.

3.6.4 Indonesia

The major wetlands selected are (See Figure 3.2):

Figure 3.2 **The major wetlands for Indonesia study within the ciliwung - Cisadane River Basin. They include:**

1) Muara Angke,
2) Muara Gembong, and
3) Tanjung Sedari



Source: Uktolseya and Wibowo, 1995

1. Muara Angke, mouth of Angke River, Jakarta Bay.

Types of wetlands: Mangrove forest (172.62 ha), swamps, estuary, riverine, tidal flats, brackish water ponds.

2. Muara Gembong, Tanjung Karawang, at the north of Jakarta Bay.

Types of wetlands: Estuarine, mangrove, peat swamps, mudflats, fish ponds (tambak).

3. Tanjung Sedari, Citarum delta, mouth of Citarum River maps, north-east of Jakarta.

Types of wetlands: Estuarine, mangrove (± 1,000 ha), tidal flats, riverine, brackish water, ponds.

Table 3.1 Uses of coastal wetlands

Muara Angke	Muara Gembong	Tanjung Sedari
- agriculture - brackish water ponds - housing - harvesting of tree/woody vines - power plant (PLTU) - recreation - harbour - collection of invertebrates for souvenirs - sport fishing	- brackish water ponds - housing - paddy fields - capturing of birds by netting or air-rifles	- brackish water ponds - paddy fields - housing - logging - waste disposal

Threats from development

Muara Angke	Muara Gembong	Tanjung Sedari
- development of land for housing - conversion of buffer zone area to dry land for recreational facilities like golf courses - industrial and domestic wastes flowing from the Angke River which affect the quality of the water in the surrounding area	- development of land for housing - industrial and domestic waste flowing from the Citrarum River affects the quality of the water in the surrounding areas - bird capture in the area may threaten the waterbird population	- conversion of wetlands brackish water ponds may threaten the wetland habitat - bird capture in the area may threaten the waterbird population

Long- and short-term impacts

Muara Angke	Muara Gembong	Tanjung Sedari
- conversion of wetlands to brackish water ponds may lead to a decrease in biodiversity in the short-term - loss of habitats for fishes and other invertebrates - decreased fish productivity in adjacent areas - degradation of the coastline due to waves and current as the result of the removal of mangrove forest - destruction of wetlands causing flooding as the "sponge" effect of the wetlands is lost - phytoplankton blooms resulting from eutrophication in the estuarine habitat cause death to the other organisms in the area	- decreased biodioversity as a result of habitat destruction - degradation of the coastline due to waves and current as result of the removal of mangrove forest	- habitat changes - changes in the coastline because of mangrove destruction

Source: Uktolseya and Wibowo, 1995

Management practices (in place or planned)

1. Muara Angke

Mangrove forest in Muara Angke is a Strict Nature Reserve managed by the Directorate General of Forest Protection and Nature Conservation (PHPA). As such, no human activities are allowed.

2. Muara Gembong

Muara Gembong is managed by the State Forest Enterprise (Perum Perhutani). Undisturbed mangrove forest is under the management of the Directorate General of Forest Protection and Nature Conservation and is currently being proposed as a Strict Nature Reserve.

3. Tanjung Sedari

Almost all the area is under the management of Perum Perhutani.

Assessment of coastal wetlands (Report card)

Categories	Muara Angke	Muara Gembong	Tanjung Sedari
State of knowledge on ecology	just sufficient/ inadequate	just sufficient/ inadequate	just sufficient/ inadequate
Nature of disturbance: Extent?	some distrubance/ severe disturbance	some disturbance/ severe disturbance	some disturbance/ severe disturbance
Management options: Existing?	negligible management/ no management	negligible management/ no management	negligible management/ no management
Management effectiveness: Effective?	just sufficient/ ineffective	just sufficient/ ineffective	just sufficient/ ineffective

All the areas assessed were deemed to be between moderate to severe damage. This is a result of the area being under severe pressure both from human activities and natural causes.

3.6.5 Republic of Korea

The major wetlands selected are situated in coastal areas between Kum River and Youngsen River on the west coast of the Republic of Korea.

This coastline is quite complex with submerged features and scattered with hundreds of islands. The area also includes the Mankyung and Donglin Estuary system. Sedimentological features range from muddy (clay and silt) tidal flats to sandy and rocky shores. Heavy loads of sediments and nutrients (especially nitrate and silicate) enter the coastal area during the monsoon season. High energy waves erode the coastline significantly.

Uses of coastal wetlands

- Shellfish mariculture
- Kelp harvesting
- Land reclamation

Threats from development

- Cheap land for infrastructure development (*e.g.*, Liquid Natural Gas (LNG) base, shipyard, industrial estate, estuarine dam for irrigation)
- Cooling of Kwangyang Bay nuclear power plant using the water from the coastal wetland
- Damming of the Keum and Youngsan Rivers for the construction of a freshwater lake to irrigate rice paddies
- Contamination of irrigation water at the Sihwa (freshwater) Lake project due to industrial estates nearby
- Land reclamation for a shipyard on the Hwawon Peninsula near the Youngsan Estuary which affects mariculture and fisheries in that area

Long- and short-term impacts of threats

Short term effects of land reclaimed:

- Reduced marine resources (*e.g.*, fisheries, shellfish, benthic fauna and flora)

Long term effects of estuarine dams:

- Changes in the physical and chemical environments which subsequently affect the biological environment
- Prohibitions on the migration of fish (*e.g.*, eel and salmon)
- Eradication of the marine biota upstream and tidal flats

Management practices (in place or planned)

Local government bodies have recently been set up to oversee the regulation of pollution and to coordinate pollution prevention measures between neighbouring communities.

Assessment of coastal wetlands (Report card)

Categories	Kum Estuary	M.-D. Estuary	Youngkwang Bay	Youngsan Estuary
State of knowledge on ecology	satisfactory	just sufficient	just sufficient	just sufficient
Nature of disturbance: Extent?	some disturbance	minimal disturbance	some disturbance	some disturbance
Management options: Existing?	some management	some management	some management	some management
Management effectiveness: Effective?	satisfactory	satisfactory	satisfactory	satisfactory

3.6.6 Malaysia

The major wetlands selected are situated in the catchment between Selangor river in the south and Bernam river in the north of State of Selangor, Peninsular Malaysia. See Figure 3.3.

This site was selected because various land use patterns exist within the area. This includes forested catchment on hilly areas, large scale agriculture plantations, peat swamp forest, ricefields, and coastal fringed mangrove.

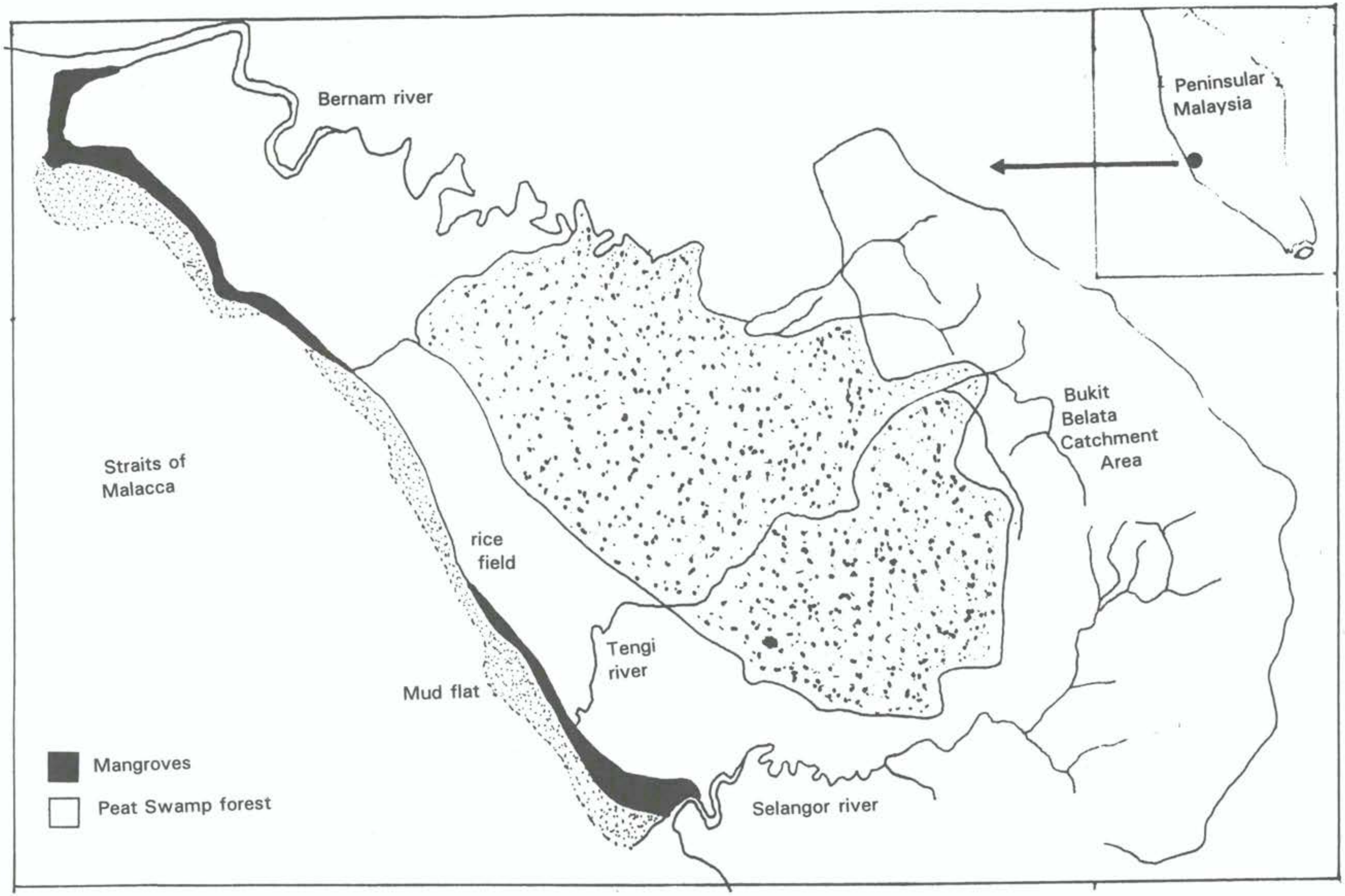
Uses of coastal wetlands

- Oil palm plantation
- Controlled logging
- Ricefields
- Harvesting of minor forest produce

Threats from development

- Reclamation
- Coastal erosion
- Pollution

Figure 3.3 The extent of coastal wetlands and catchment areas between the Selangor and Bernam rivers, Selangor, Malaysia.



Source: Ibrahim and Chan, 1995

Management practices (in place or planned)

There is no clear and definite policy over wetland management in the country. Management is currently being guided by three major existing policies (National Forest Policy, National Policy on Biodiversity, and National Environment Policy). These three policies may not be adequate to safeguard the wetland ecosystems, especially with regards to maintaining ecological characteristics of coastal wetlands.

A guideline was prepared by the Malaysian National Mangrove Committee (NATMANCOM) on the proper use of mangrove ecosystems for aquaculture. The guideline was created with the aim to integrate pond culture with other mangrove functional ecosystems and acts as a supplementary guideline to an existing mangrove management plan. However, this guideline does not have a bench-mark when it makes recommendation that a certain percentage per annum of mangrove can be removed. The result is that the mangrove forest will be decreased in subsequent years since the percentage will be based on current year status.

3.6.7 The Philippines

The major wetlands selected are situated in the Lingayen Gulf in Northern Luzon. The Agno River Basin empties its contents into the Gulf of Lingayen. See Figure 3.4.

This site represents all three coastal ecosystems, (*i.e.*, coastal wetlands, seagrass ecosystems, coral reefs).

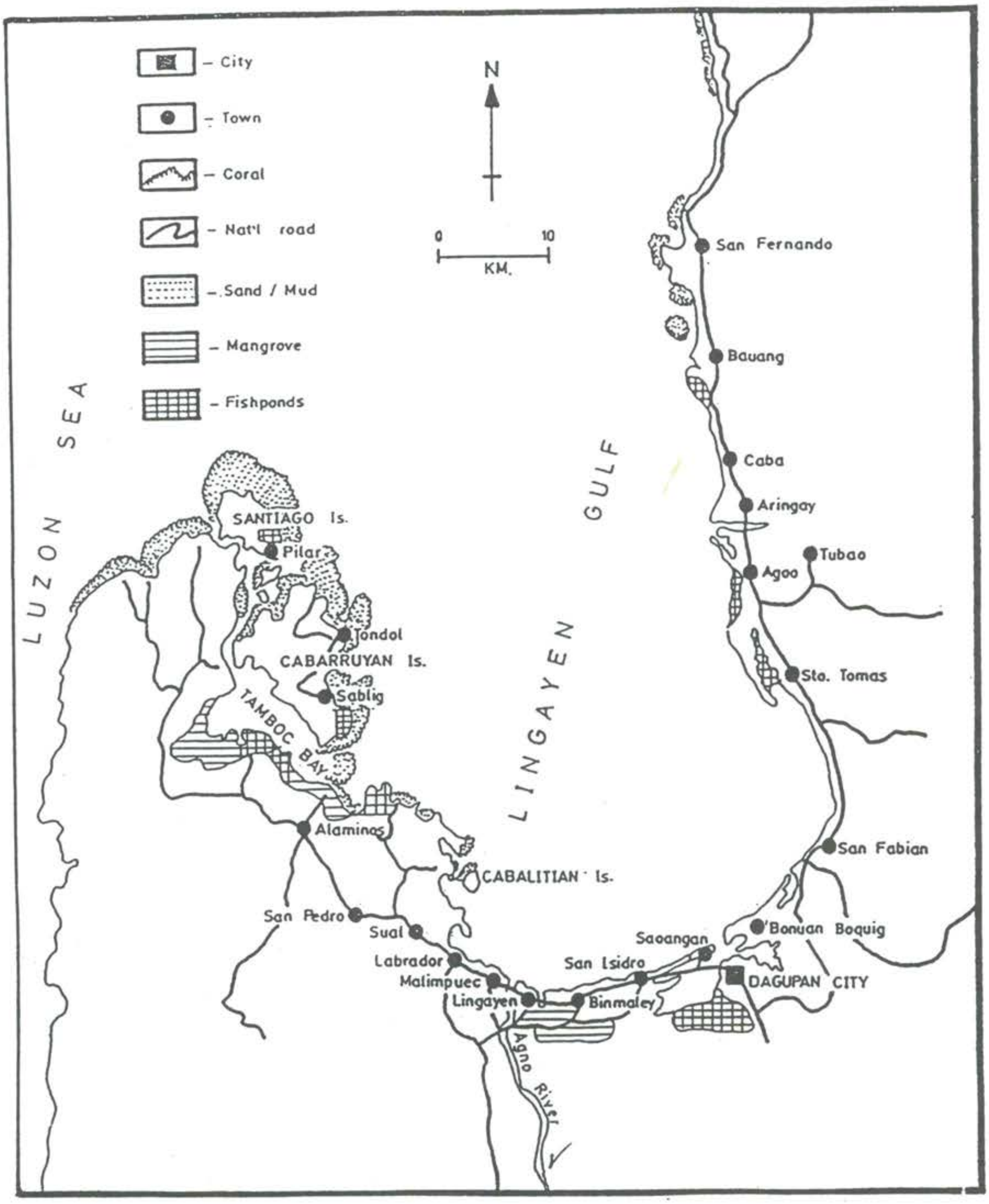
Uses of coastal wetlands

- Brackish-water aquaculture
- Harvesting of shells for sale and shellfish for home consumption
- Harvesting of fish and shrimp fry to be sold to pond operators
- Gathering of sea cucumbers, sea urchins, and seaweed for food
- Recreation sites for ecotourism

Threats from development

- Aquaculture
    - Clearing of mangrove forest for aquaculture
    - Intensive usage of fertilizers and pesticides with the intensification of aquaculture
- Industrialization/Urbanization
    - Increased solid waste and waste water to a very significant level
    - Vacant lots of land and river systems used as dumpsites
    - Lack of sanitary sewerage systems for domestic wastes
    - Accumulation of solids ranging from biodegradable wastes to persistent solids
- Upland Activities
    - Mining
    - Logging
    - Agriculture

Figure 3.4 Detail of land-uses in the Lingayen Gulf in Northern Luzon, the Philippines.



Source:Lonzo-Pasicolan, 1995

Long- and short-term impacts of threats

- Loss of mangroves as pollution sinks for effluents from mining, logging, agriculture, fisheries, and domestic activities.

- Siltation from the mining operation on the upper reaches of the Agno and Bued Rivers causes:

  - Shallowing of rivers
  - Cementing action on soil layers which inhibits the natural regeneration of mangroves; and
  - Formation of toxic compounds which accumulate as a result of anaerobic soils
  - Death of soil microorganisms

- Siltation from activities other than the mining operation at the upper reaches of the Agno and Bued Rivers caused by soil erosion from illegal forest occupancy, illegal logging, fuel wood gathering, and slash and burn farming.

- Low dissolved oxygen levels and low transparencies and high suspended solids concentrations due to the decomposition of organic matter

- Lead, cadmium, mercury, iron, copper, and zinc concentrations are above the Department of Environment and Natural Resources (DENR) standards

- Nutrient and toxic chemical loads are great due to:

  - Domestic effluents
  - Leaching from the soil
  - Organic/inorganic fertilizer and pesticides from farms and fishponds

  All this heavy pollution results in a low fish catch per unit effort

Management practices (in place or planned)

- Reforestation of denuded areas (*e.g.*, Communal Tree Farming (CTF), Family Approach to Reforest (FAR) and the Industrial Tree Plantation Programmes)

- Massive mangrove rehabilitation is supervised by the Community Based Mangrove Forest Management (CBMFM)

- DENR prepares coastal communities to accept new concepts of forest management

- DENR provides security of tenure and credit facilities for alternative income-generating livelihoods based on sustainable resource utilization

- DENR passed an Administrative Order regulating the utilization and management of mangrove resources

- Intensive education and communication activities were also launched as a tool to bring about conservation awareness and foster participation of communities in all government programmes

Assessment of coastal wetlands (Report card)

Categories	Lingayen Gulf
State of knowledge on ecology	inadequate
Nature of disturbance: Extent?	severe disturbance
Management options: Existing?	some management
Management effectiveness: Effective?	satisfactory

Impact of wetland on coral reefs and seagrass beds

Destruction of the mangroves leads to the loss of nursery grounds for fish and shellfish, and protection of the coastal areas against sedimentation, nutrient, and pollution loading from the land. Seagrasses and coral reefs are being killed by smothering and by toxic chemicals. Genetic and species diversity is lost as the protective belt provided by the mangroves is destroyed.

3.6.8 Singapore

In 1819, when Singapore was founded, lush mangrove forests covered much of Singapore's coastline (10 - 13% of the land area). The area occupied by Mangroves has continualy been diminished by development, and today less than 1% (600 ha) remain. See Figure 3.5. The major wetlands selected cover small pockets of mangroves in Sungei Buloh, Mandai, Kranji, and Lim Chu Kang. A few remnant stands remain on the offshore islands of Pulau Ubin and Pulau Tekong in the north, and Pulau Semakau and Pulau Pawai in the south.

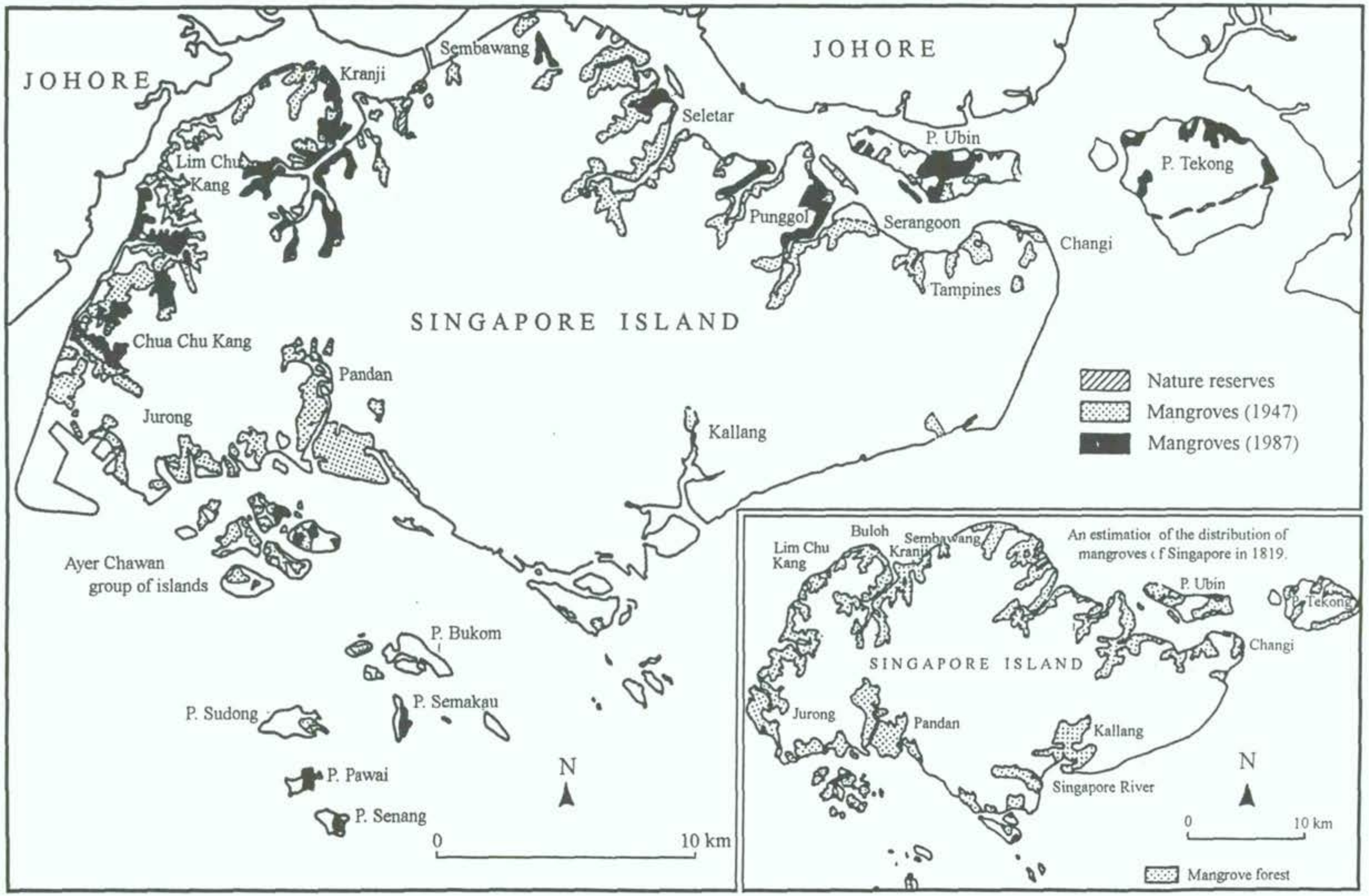
Uses of coastal wetlands

- Harvesting of mangrove trees for firewood, charcoal and poles, and the *Nypa* palm for sugar and seeds
- Harvesting of seafood
- Prawn and poultry farming
- Extensive development for industry and housing with increased urbanization
- Scientific research (*e.g.*, impacts of oil pollution, and heavy metal concentrations in marine sediments; taxonomy of crabs, fishes, insects, and the benthic soft-bottom community; faunal zonation at Pandan mangroves, and elucidation of zonal patterns of mangrove trees)

Threats from development

Mining and logging do not pose a danger to the present coastal ecosystems as Singapore has very few natural resources. In the past, prawn, poultry farming and small scale agriculture were responsible for some mangrove deforestation but are now in decline. Development of the coastal areas for industry and housing projects remains the major threat to the destruction of mangroves and related ecosystems. Run-off of fine sediment into the marine environment poses a threat to offshore ecosystems.

Figure 3.5 Past and present mangrove coverage along the coast line of Singapore.



Source: Low and Chou, 1995

Management practices (in place or planned)

- Specific laws for the protection of the mangrove forest do not exist as yet. All wild animals are protected under the Wild Animals and Birds Act (WAB) 1974. The Parks and Trees Act of 1975 includes the protection of natural habitats. A National Parks (NP) Act was introduced in 1990 for the specific protection of animals in parks and catchment areas. The Acts are administered by the Parks and Recreation Department and the National Parks Board.

- Several NGOs and several institutions are active in promoting conservation and awareness of natural habitats. The Singapore Red Data Book was compiled by the Nature Society of Singapore (NSS) and The National University of Singapore (NUS).

Assessment of coastal wetlands (Report card)

Management status of selected mangrove sites

Categories	1	2	3	4	5	6	7
State of knowledge on ecology	B	B	C	C	C	D	C
Nature of disturbance: Extent?	B	D	D	D	D	D	C
Management options: existing?	A	B	C	C	C	D	D
Management effectiveness: Effective?	A	B	D	D	D	D	D

Locations:
1 - Sungei Buloh Nature Park
2 - Sungei Tampines
3 - Sugei Api-api
4 - Mandai Besar-Lim Chu Kang
5 - Pulau Semakau
6 - Pulau Ubin
7 - Pulau Tekong

Grading key:

	State of knowledge on ecology	Nature of disturbance: Extent?	Management options: Existing?	Management effectiveness: Effective?
A	excellent	no disturbance	good management	effective
B	adequate	minimal disturbance	some management	satisfactory
C	inadequate	some disturbance	negligible management	just sufficient
D	severely lacking	severe disturbance	no management	ineffective

3.6.9 Thailand

The major wetland selected is situated in Phangnga Bay on the west coast of Thailand. It is located in the Upper South region of Thailand facing the Andaman Sea. It also covers some areas of the Phangnga and the Krabi Province. Phangnga Bay is rich in coastal resources that support a broad range of economic activities. It is also the designated site of the ASEAN/USAID Coastal Resources Management Project (CRMP). The bay is surrounded by mangrove swamps and supports one of the most extensive areas of mangroves remaining in Thailand. The total extent of the Phangnga Bay mangroves covers 19,638 ha.

Uses of coastal wetlands

Traditional uses:

- Mangrove trees for firewood, charcoal, timber, and other minor products
- Harvesting of fish, shrimps, and crabs

Modern uses:

- Aquaculture development (*e.g.*, fish, cockles, mussels, oysters, shrimps)
- Tourist attraction: caves, karst formations, national park
- Collection of edible swiftlet nests
- Extraction of tin
- Rubber plantations in surrounding areas

Threats from development

- Clearing of the mangrove forest for firewood, construction materials, charcoal-making, aquaculture, tin mining, and agriculture
- Conversion of mangrove forest into agricultural land or shrimp ponds

Long- and short-term impacts of threats

- Sedimentation

Sedimentation is mainly due to mine tailings with minor contributions from communities and industries (oil palm mills and rubber plants). Mining activities affect the mangrove community and destroy the fauna directly. Sedimentation affects aquaculture, fisheries, and sometimes navigation. The discharge of sediments into the rivers or the mouth of the Bay reduces cockle population.

- Nutrient-loading

Most coastal wetlands are probably not seriously affected by nutrient loads in the short-term but tend to "lock" them up by acting as a nutrient trap. In the long-term, the nutrient load might cause algal blooms and affect the fish, crustacean, and shellfish populations. The increased oxygen demand resulting from coastal eutrophication might also smother shellfish and affect reproduction and recruitment.

High nutrient contents (PO_4 and NO_3) are generated upstream during the northeast monsoon. These are diluted by water downstream and moved into the bay during the ebb tide.

- Pollution

Small amounts of waste were generated by the Muang Phangnga and Muang Krabi communities. Wastes from oil palm mills and smoked rubber plants were retained within the plants. These did not have a significant impact on the water quality of the natural receiving waters. Dissolved oxygen (DO) and biological oxygen demand concentrations indicate that the water quality in the Phangnga Bay was within the acceptable limits of the National Surface Water Quality Standards. High coliform bacteria counts were also recorded during the low tides and the wet season. This was due to occasional sewerage discharges into the bay. High coliform counts were also recorded near the communities of Muang Phangnga and Muang Krabi. This led to a decline in the water quality around the area. This could be due to the flushing of coliform containing particles into the natural receiving waters during storms.

Intensive mariculture sites, usually associated with human settlements, can cause very turbid waters. Excess fishmeal from these sites constitutes a high Organic Fraction (OF) of up to 63 ppm. Microbial decomposition causes very low levels of DO (<3 ppm). DO in heavy culture areas drops as low as 1.5 ppm at night causing hypoxia. The restriction of water movement around the water cages causes a drastic drop in the total alkalinity value (<60 ppm $CaCO_3$). This low value is favourable for bacterial growth and a high coliform bacteria count was recorded (1,700 MPN/100mL).

Mangroves are being cleared for shrimp farming. Approximately 77.5% of the nitrogen and 86% of the phosphorus content in shrimp feeds settle to the bottom of the pond (either as dissolved feed or shrimp excreta) and ferments under anaerobic conditions. The sludge thus formed can enrich the coastal waters and cause algal blooms. Antibiotics and chemicals for soil treatment used in shrimp farming are often discharged with the waste water into the coastal waters, further damaging the ecosystem.

Management practices (in place or planned)

Intermediate Programmes:

- Study of mine effluents and review of the standards for suspended and settleable solids in mining effluents
- Development of community sanitation at Pan Yee and Phi Phi Islands
- Solid waste management at Pan Yee Island
- Development of on-site wastewater treatment facilities at Amphoe Muang Krabi and Amphoe Muang Phangnga
- Environmental monitoring programme on the Phangnga and Krabi Rivers

Long-term Programmes:

- Study on the management of unused mines
- Study on the management of road construction, especially roads to mining sites

Assessment of coastal wetlands (Report card)

Categories	Mangrove	Mudflats	Watersheds
State of knowledge on ecology	reasonable	reasonable	reasonable
Nature of disturbance: Extent?	some disturbance	some disturbance	some disturbance
Management options: Existing?	some managment	some management	some management
Management effectiveness: Effective?	satisfactory	satisfactory	satisfactory

Impact of coastal wetlands on reefs and seagrass beds

Suspended solid particles from mine tailings affect mangroves, seagrass beds, and corals. Many areas of coral have already been damaged. In Phangnga Bay, no species of seagrass were found. Six species of seagrass are found around the outer bay.

3.6.10 Vietnam

The wetlands selected were the Tam Giang - Cau Hai lagoon ecosystem (TG-CH lagoon) and those situated in the Red River Delta. See Figure 3.6.

The Tam Giang - Cau Hai lagoon is divided into three parts; i.e., Tam Giang, Thuy Tu, and Cau Hai.

The types of wetland in the TG-CH lagoon include (See Figure 3.7):

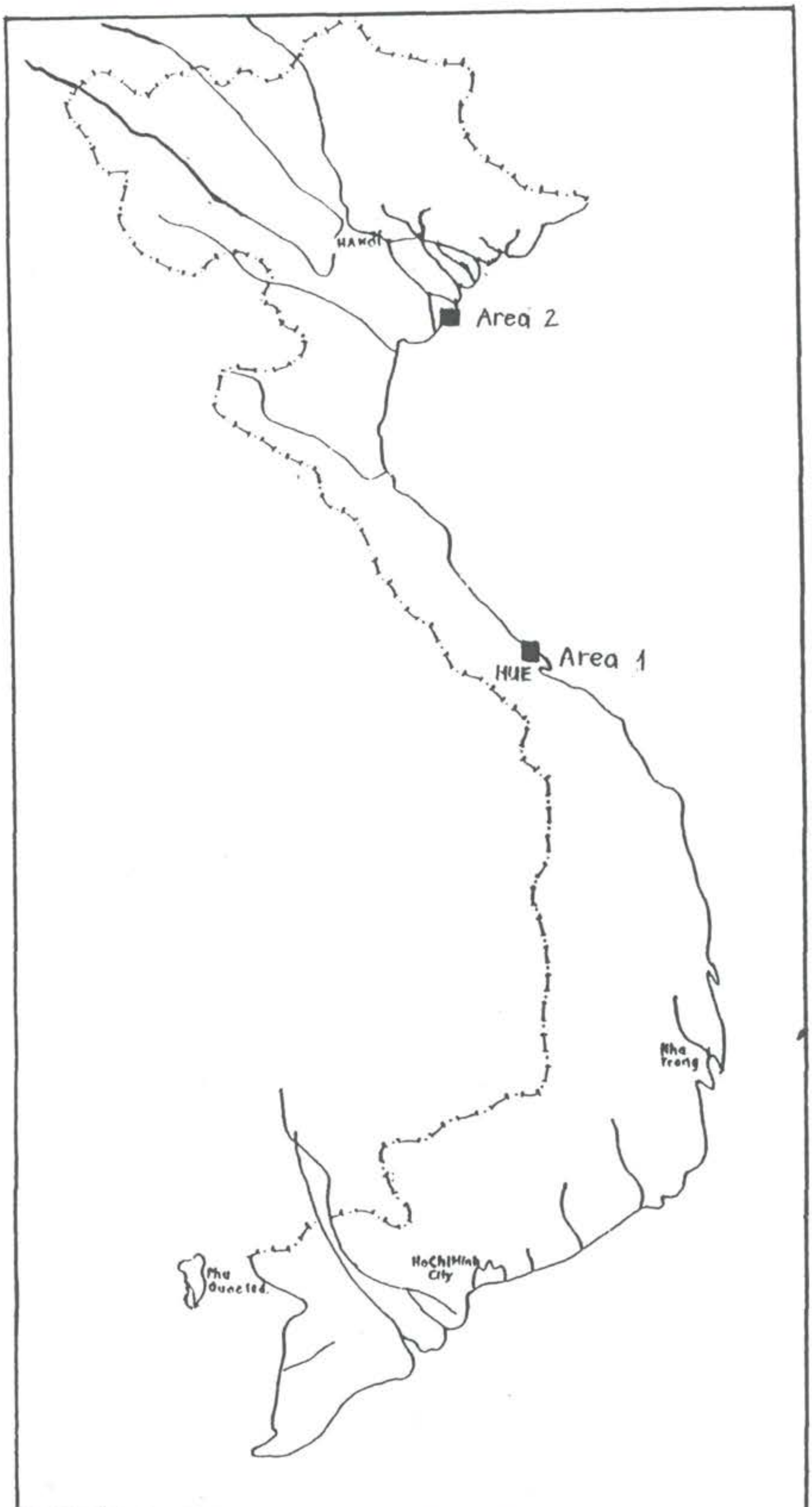
- Vegetated wetland: marshes with Phragmites and *Cyprus* sp.
- Non-vegetated wetland: sandy tidal wetland, muddy tidal wetland, rocky coast
- Water body: Lagoon lake, River mouth, creeks (inlets)

The Red River has a large delta area, high tidal flats with mangroves, low tidal flats, and river mouth barriers. Total area: 26,000 hectares.

The types of wetlands include (See Figure 3.8):

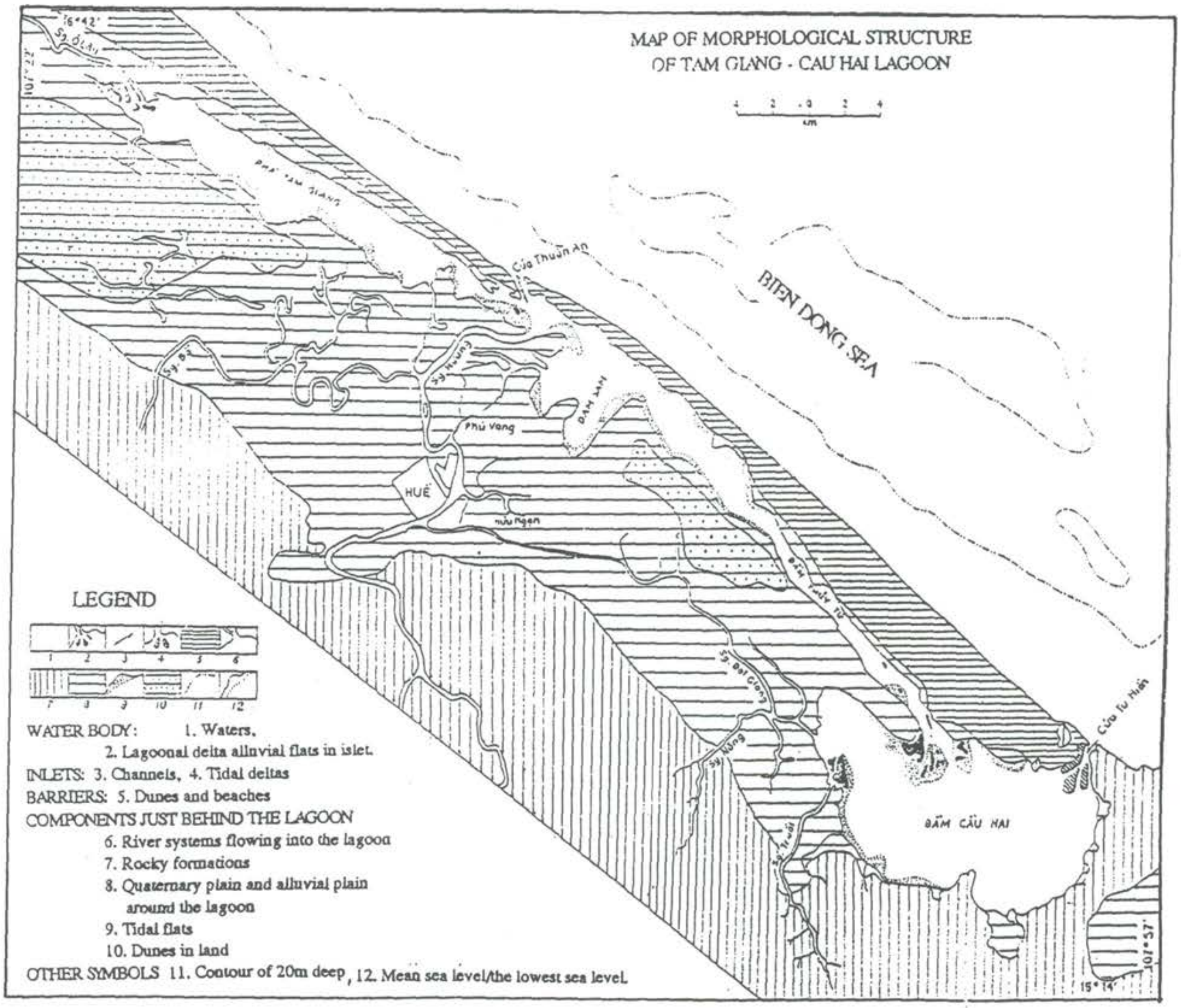
- Wetlands with vegetation:
  - i. mangrove (1,844 ha)
  - ii. seagrass (281 ha)
  - iii. barriers (660 ha)
- Wetlands without vegetation:
  - i. mud flats (4,156 ha)
  - ii. sandy mud flats (3,148 ha)
  - iii. sand barriers and bars (946 ha)
- Man-made wetlands:
  - i. reclaimed land (322 ha)
  - ii. aquaculture (3,450 ha)

Figure 3.6 **The study sites selected in Vietnam:**
1) the coastal wetland of the Tam Giang - Cau Hai Lagoon;
2) the coastal wetland of the Red River Delta.



Source: Chu Hoi, Duc Thanh, Duc Cu, Dinh Lan, Dinh Chien, and Van Thouc, 1995

Figure 3.7 Morphological Structure of Tam Giang - Cau Hai Lagoon.



Source: Chu Hoi, Duc Thanh, Duc Cu, Dinh Lan, Dinh Chien, and Van Thouc, 1995

- Tidal wetlands:
  - i. river beds (702 ha)
  - ii. tidal creek beds (82 ha)
  - iii. downstream delta (10,400 ha)

Uses of coastal wetlands

Tam Giang - Cau Hai lagoon:

- Housing: on land and on boats in the lagoon
- Use of the lagoon as an inland waterway
- Development of Tan Thuan Port
- Development of tourism in lagoon
- Exploitation of watergrass and algae as fertilizer for agriculture
- Fishery industry
- Aquaculture, mainly shrimp, *Gracillaria*, fishes, and crabs

Red River:

- Exploitation of natural sea products (*e.g.*, shellfish and crabs)
- Exploitation of mangroves (*e.g.*, firewood, agriculture, and breeding of honey bees)
- Land reclamation

Threats from development

Tam Giang - Cau Hai lagoon:

- Destruction of forest upstream; large areas of forest were destroyed by herbicides during the war and continue to be destroyed by cultivation
- Development of urban and agricultural populations upstream and around the area of the lagoon
- Upstream and coastal construction
- Domestic activities of inhabitants living on the border of the lagoon and on the lagoon
- Fishery industry

Red River:

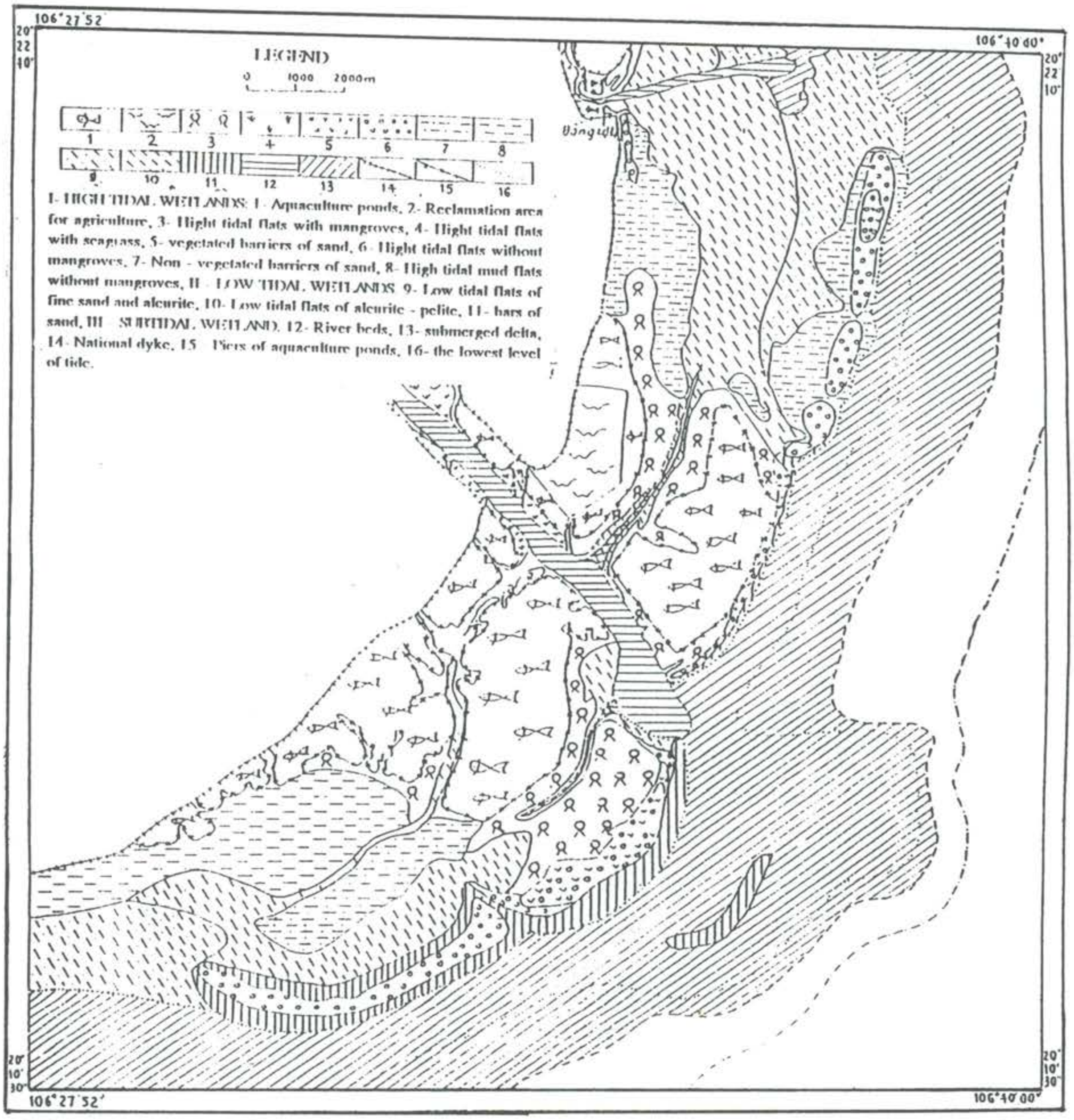
- Aquaculture
- Land reclamation for aquaculture
- Agro-chemical pollution
- Over-exploitation of sea products
- Livestock grazing

Long- and short-term impacts of threats

Tam Giang - Cau Hai lagoon:

- Long-term, pollution, from oil, organic, urban and industrial waste, pesticides and chemical fertilizer. Tourism development in the future will contribute to the pollution problem.
- Restriction of water circulation in the lagoon due to the development of dikes for salt prevention, aquaculture ponds, cages, rafts, and trapping baskets which are packed very densely together. The problem is compounded by the closure of the Tu Hien inlet.

Figure 3.8 Map of tidal wetlands in the Red River Delta.



Source: Chu Hoi, Duc Thanh, Duc Cu, Dinh Lan, Dinh Chien, and Van Thouc, 1995

- Decreased living resources and degradation of the ecosystem due to over exploitation especially of seagrass beds being harvested as fertilizers for agriculture
- Flooding and inundation
- Freshening of lagoon water
- Increased salinity of coastal waters during the dry season
- Lack of nutrients in lagoon waters
- Movement and closure of river inlets due to sedimentation
- Shallowing of the water body

Red River:

Direct impacts

- Building aquaculture ponds requires clearing of mangroves. 3,500 ha of mangroves were cleared for aquaculture between 1990-1995. Production of honey dropped from 100-120 tons/year to 30-50 tons/year.
- Overfishing has reduced the production of sea products to between 1/3 to 1/2 of previous production
- Pesticide pollution in the tidal wetlands
- Hunting and trapping of birds

Indirect impacts

- Human activities such as overfishing, pesticide pollution, hunting of birds, destroy the habitat and reduce the nursery area for crabs, fish, and prawn juveniles
- This results in the reduction of fish production near the Red River mouth

Management practices (in place or planned)

Tam Giang - Cau Hai lagoon:

- Reforestation in the upstream area has been carried out in the past few years and prevents flooding and the flushing of the lagoon
- Building dikes for the prevention of salt intrusion into agricultural and inhabited areas
- Building dams to prevent salt intrusion upstream
- Conversion of salt wetlands into aquaculture ponds
- Strengthening of aquacultural methods by cages and rafts instead of pond development
- Preventing the Tu Hien inlet from being enclosed due to sedimentation
- Implementating a Settlement Policy for the people living on boats in the lagoon
- Encouraging the development of an open sea fishery

Red River:

- Traditional Management:

  Managed by coastal village administrators and strictly obeyed by the villages. Mainly tidal flats with natural or planted mangroves for the protection of dikes.

- Plans for mangrove reforestation:

  The coastal zone villages plant about 100 to 300 ha of mangroves per year.

- Management of the implemented plans:

  The protection, establishment, and management of protected areas is carried out by the government and international organizations for the protection of natural resources.

Assessment of coastal wetlands (Report card)

Tam Giang - Cau Hai lagoon:

Management of the lagoon wetland is not suitable and effective due to:

- High density of fishing boats and labour compounded by the use of primitive fishing gears and technologies has led to the over exploitation of living resources. This also affects the biodiversity and the ecosystem.

- Gaps in scientific knowledge which cause great difficulty in the implementation and execution of management policies.

- Conflicts between social development and the sustainable management of resources.

- Floods and salt intrusion which exert pressure on the living resources and cause degradation of the ecosystem.

- Lack of funds and technologies in utilising the lagoon wetland.

- Loopholes in the regulations that control exploitation of natural resources

Impact of wetland on seagrass beds:

There is abundant production of seagrasses in Tam Giang-Cau Hai lagoon. Five species have been identified, and biomass is high. Increasing turbidity and decreased salinity of the surrounding waters are the most dangerous threats to the seagrasses. Destructive fishing activities and the collection of seagrasses as fertilizer also threaten the seagrasses. Oil pollution is another major factor. There is no report on the seagrass communities at the mouth of the Red River.

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SECTION 4. WATERSHEDS IN THE EAST ASIAN SEAS REGION

4.1 INTRODUCTION

4.1.1 Status of Watersheds in the Region

In most of the countries in the East Asian Seas (EAS) region, the rivers that discharge into the seas have their watersheds mainly situated within their respective national boundaries. This is true for 100% of the watersheds in Indonesia, the Philippines, Singapore, and Australia; and almost true for the Republic of Korea and Malaysia. The only major river that crosses a number of countries is the Mekong River, having its watershed in the EAS countries of Cambodia, People's Republic of China, Thailand, Vietnam, Laos, and Myanmar.

Therefore, apart from the Mekong River watershed and the Red River, all issues concerning the integrated management of specific watersheds in relation to the coastal and marine environments are subject to the jurisdiction of only the respective member countries in the East Asian Seas region. This also means that most of the upstream activities that have downstream impacts on the environment can be addressed by the institutions of a single country. This is an important asset because it will greatly simplify the decision making process to implement relevant management plans.

Within each country, however, most watersheds cover a large number of regional administrative units. Furthermore, the subject matter of integrated watershed management cuts across the mandates of many ministries and their relevant departments and also requires the involvement of a multitude of professionals with various expertise. In this context, the following types of integration within watersheds need to be considered:

- Inter-territorial integration that is across administrative units, based on the partition of a country into sub-national territories;
- Inter-departmental integration across the authoritative mandates of the various departments involved; and
- Inter-disciplinary integration that is across two or more disciplines.

In addition to these three types of integration within watersheds, there is a need to integrate watershed management with its downstream effects on coastal and marine ecosystems, with special emphasis on the coral reefs, seagrass beds, and coastal wetlands (which may have interlinkages between them as well). This leads to a fourth type of integration:

- Inter-ecosystem integration across watersheds, coastal wetlands, seagrass beds, and coral reefs.

4.1.2 Major Factors that Lead to Sedimentation, Nutrient-Loading, and Pollution into Downstream Environments

When discussing sedimentation, nutrient-loading and pollution (SNP) that rivers discharge into the downstream environment, it will be necessary to distinguish between the natural situation of pristine rivers and the anthropogenic changes in water discharge and the SNP loads of the rivers. This distinction has to be made because it is the anthropogenic changes that will most greatly affect the natural conditions of the coastal and marine environment. This section will therefore focus on anthropogenic changes, which can be either a change in the total volume of water and SNP or a change in their temporal distribution, or both.

i. Water

Apart from anthropogenic long-term changes to the climate, the annual net precipitation on a watershed is a natural factor that determines the annual flow of open rivers not affected by man.

If, however, dams are constructed for irrigation, flood control, water supply, and/or hydroelectric power generation, evaporation from the water storage will decrease the annual volume of water discharged downstream; and the operating procedures of the reservoir will affect the temporal distribution of the downstream river discharges.

Another factor that will result in a change in the instantaneous water discharge of a river is a change in land-use within the watershed. This leads to changes in the run-off factor of the surface areas and/or in the retention factor of sub-surface water in the topsoil.

ii. Bed material

In natural rivers, at any point along their longitudinal profiles, there is an equilibrium between the grain size of its bed material, the gradient of its water surface, and its water discharge. These three factors mainly determine the quantity of bed material that is transported downstream. As the grain size of the bed material and the slope of the bottom of an open river are natural phenomena, only changes in the water discharge will affect the bedload capacity of a river. When dams are constructed, the slope of the water surface will decrease within the reservoir and most of the bed material from the upstream part of the river will be deposited in the reservoir.

iii. Suspended solids

The suspended solid load of a river, which is mainly made up by the fine sand and silt component of the sediment, is kept in suspension by the turbulence of the water. Under natural conditions, the main sources of fine sediments are the materials eroded from the riverbanks and the adjacent floodplains. Anthropogenic changes in land-use have in many cases resulted in increased levels of soil erosion. This increased availability of sediments leads to increased loads of suspended solids in the river. Again, as is the case with bed material, the construction of reservoirs in a river greatly affects the downstream suspended solids load, because suspended solids will tend to settle in the reservoirs due to low turbulence in the reservoirs.

iv. Nutrients

The natural concentrations of plant nutrients (mainly nitrogen and phosphorus) in river water are relatively low. This is because of the balance between the available nutrients in the topsoil and the nutrient uptake by the natural vegetation. Anthropogenic changes in the natural vegetation will upset this natural balance.

When the natural vegetation is removed, soil nutrients can be leached out and/or be eroded away into a river or water course. Also, when the agricultural crop uptake of nutrients is substantially less than the addition of organic and inorganic fertilizers to farmland, there will be an excess of nutrients that can be leached/eroded into the surface waters of the watershed. Furthermore, industrial wastewaters and domestic sewage contain nitrogen and phosphorus compounds.

v. Toxic chemicals

Increasing concentrations of chemical substances originating from industrial, agricultural, and other human activities have been detected in the air, water, and soils. Such concentrations, coupled with bio-accumulation of some of these substances, have given rise to environmental and ecotoxicological effects, which are of major concern to the coastal and marine ecosystems. In this respect, three major groups of chemicals require special attention; i.e., heavy metals and metalloids, polychlorinated biphenyls (PCBs), and pesticides.

Heavy metals and metalloids of particular concern are lead (Pb), mercury (Hg), cadmium (Cd), and arsenic (As). The PCBs are chemicals that do not occur naturally in the environment. The same can be said of most of the pesticides, which embrace a wide variety of chemical compounds, and can be divided into insecticides, fungicides, and herbicides.

vi. Organic Pollutants

The major sources of organic pollution are from domestic, agricultural (livestock), and industrial wastewaters and solid waste disposal sites. When such organic pollutants (with or without prior treatment) reach surface waters, the oxidizable part of the organic matter will decay with time, subject to the availability of sufficient dissolved oxygen (or other sources of oxygen) in the water. This means that the organic pollution load will decrease as a function of time; *i.e.*, in a flowing river, as a function of distance from the point of discharge into the river.

4.2 REGIONAL ASSESSMENT

4.2.1 Study Sites

With respect to the watersheds, the national inventories focus in some detail on one watershed in each of the participating countries, instead of giving a rather general impression of all watersheds. This approach has resulted in good insight into the problems related to the preparation of such inventories and the level of information generally available on the subject.

However, given the geographical limitations of the inventories *vis-à-vis* the total land area of countries concerned, this thematic overview of the watersheds in the East Asian Seas region cannot be considered a representative, all-encompassing document. It should therefore be treated as only indicative of the situation in the region. For easy reference, the study sites in the watersheds in each of the ten participating countries are listed below in Table 4.1.

The synopses of the national inventories of these watersheds are presented in section 4.6.

Table 4.1 Area of study site of watersheds

Countries	Watershed	Surface area of watershed (km^2)
Australia	Herbert River	± 10,000
Cambodia	Seven coastal rivers	± 14,500
China	Pearl River	± 453,100
Indonesia	Ciliwung-Cisadane Basin	± 6,000
Korea	Kum River and Yongsan River	± 12,800
Malaysia	no specific river	
Philippines	Agno River	15,122
Singapore	Singapore Island	580
Thailand	Tapi-Phum Duang River	11,585
Vietnam	Five major rivers	± 180,000

Source: EAS-35 National Inventories, 1995

4.2.2 Major Potential Sources of Sedimentation, Nutrient-Loading, and Pollution (SNP)

i. Sedimentation

In almost all national inventories, the changes in the patterns of land-use within the watersheds concerned are said to be the potential sources of the increased levels of suspended solids in the rivers which drain these watersheds. Apart from China, which reports a 15% to 20% increase in the suspended sediment load per decade between the 1950s and 1980s in the East River and North River of the Pearl River system, no other time series observations have been presented to quantify such a trend. However, the inventories contain a number of references that substantiate the qualitative interlinkage between changes in land-use patterns and the level of soil erosion.

Not all soil material that is eroded from the land surface necessarily ends up in the river because it may be deposited (at least in the short-term) elsewhere in the watershed. In the national inventory of the Pearl River watershed in China, which mentions a high incidence of soil erosion, it is reported that the ratio between the actual sediment load in the Pearl River and the volume of soils eroded from the watershed is on the order of 0.4. This would mean that about 60% of the annually eroded soils do not (yet) reach the river. Nevertheless, if changes in the patterns of land-use result in an increased incidence and intensity of soil erosion, it is most likely to result in more soil particles (eventually) reaching the river and more sediments being transported downstream and (eventually) reaching the coastline.

The following list presents a summary of activities that are reported in the national inventories as causing increased levels of soil erosion:

Disruption of the natural vegetation cover:

- Deforestation
- Construction sites (infrastructural works, industrial estates, housing complexes)
- Slash and burn practices
- Open mining operations

Application of unsound agricultural practices:

- Use of marginal lands
- Use of steep lands
- Insufficient vegetation cover
- Insufficient soil conservation measures
- Overgrazing of pasture land

The above-cited activities are strongly related to changes in the land-use patterns, mainly in response to increasing population pressures. This will result in the need to expand the arable area for increased food production by encroaching into forest, woodlands, and marginal lands. This is accompanied by a parallel loss of prime agricultural lands to human settlements, industrial sites, and infra-structural works. In addition, much of the land that is being farmed is losing its productivity because of poor agricultural practices (Oldeman et al., 1990). The estimated extent of degraded land in selected countries in the EAS region expressed in percentage of the total land area of each country is as follows (Dent, 1989):

China	30.0%
Indonesia	24.0%
Philippines	16.8%
Thailand	33.7%
Vietnam	48.9%

These figures should be seen in the perspective of the land-use patterns in the EAS region as summarized in the Table 4.2:

Table 4.2 Land-use in the EAS region (excluding Australia and Singapore)

Countries	Total land area (km^2)	Arable land % of total	Pastures % of total	Forests/ woodlands % of total	Others % of total
Cambodia	177,000	14	11	66	9
China	9,362,000	10	43	14	33
Indonesia	1,812,000	12	7	60	21
Korea	99,000	21	1	65	13
Malaysia	329,000	15	0	59	26
Philippines	298,000	31	4	34	31
Thailand	511,000	39	2	26	33
Vietnam	325,000	21	1	30	49

Source: FAO, 1994

A breakdown of the total forest cover in selected countries in the EAS region with respect to major types of forests is presented in Table 4.3 as the percentage of the total forest cover:

Table 4.3 Forest cover as a percentage of specific forest type.

Country	Tropical rain-forest	Moist deciduous	Dry deciduous forest	Hill/mountain forest
Cambodia	14	30	55	1
Indonesia	86	3	0	11
Malaysia	92	0	0	7
Philippines	48	18	0	34
Thailand	24	41	25	10
Vietnam	35	41	11	13

Source: FAO, 1993

With respect to the rate of deforestation in selected countries in the EAS region over the period 1981-1990, the annual rates as a percentage of total forest land are reported to be as follows (FAO, 1993):

Cambodia	:	1.0%
Indonesia	:	1.1%
Malaysia	:	2.0%
Philippines	:	4.0%
Thailand	:	4.0%
Vietnam	:	1.6%

The two major direct causes of forest destruction in the EAS region are clearing for agriculture (including shifting cultivation) and excessive cutting of industrial timber and fuelwood. Apart from the losses with respect to biodiversity of species and habitat for wildlife, deforestation also leads to the excessive loss of topsoil, a decline in soil fertility, poor microbial activity in the soils, frequent landslides, and increased sediment loads in rivers draining deforested areas.

Other reported sources of sediments refer to the uncontrolled dumping of mine tailings, which results in significant increases in the sediment loads (and toxic pollution) in the downstream stretches of the rivers. In the Agno River basin in the Philippines, quantified data are available on sediments in irrigation systems that can be traced back to mine tailings in the Upper Agno basin. Similarly, in the offshore coastal sediments of the Red River in Vietnam, coal particles from upstream mining activities can be considered as tracers in the riverine sediments originating from the coal mining area in the Red River watershed.

ii. Nutrients

An evaluation of the average fertilizer dose on crops covering eight of the countries that are participating in the EAS-35 Project shows a very substantial increase in the application of fertilizers over the past decades as depicted in Table 4.4.

Table 4.4 **Evaluation of average fertilizer dose on crops in selected EAS countries ($N + P_2O_5 + K_2O$) kg/ha./ annum**

Country	1960	1970	1980	1990
Cambodia	0.4	1.1	4.5	3.8
China	54.0	31.4	108.9	191.3
Indonesia	7.7	11.9	57.7	101.4
Korea	111.3	169.3	298.3	425.8
Malaysia	25.3	50.7	98.1	207.4
Philippines	8.7	22.4	29.2	50.9
Thailand	2.1	7.5	19.2	55.7
Vietnam	14.4	48.6	18.2	58.0

Source: FAO, 1994

Although these increased applications of fertilizers have resulted in higher yields of crops in tonnes/ha.annum, the efficiency of the nutrient uptake in these crops is not enough to absorb all the fertilizer applied. This is partly due to the fact that each crop has a threshold beyond which it cannot take up more nutrients. Any fertilizers applied beyond that threshold are potentially lost to the environment. The optimum level of application of fertilizers, when taking into account the cost of fertilizers, the value of the harvest, and the potential damage to the environment, lies significantly below the above cited doses to the crops concerned.

The historical development of the nitrogen balance sheet in the USA shows that the nitrogen uptake efficiencies in crops have increased from 35% in the mid thirties to 55% after World War II, then reached 65% in 1980 and are presently at about 70%. This means that the potential nitrogen losses to the environment in the USA have been reduced over a period of about 60 years from 65% to 30% of the nitrogen supply. As the total supply of nitrogen over the same period increased by a factor of about three, the potential nitrogen losses to the environment increased only by approximately 50%.

In NW Australia, it has been estimated that present day exports of nutrients from the watersheds to the coastal zone are 3 to 5 times higher than could be expected from conditions prior to European settlement (Moss et al; 1992). Much of this increased nutrient export has occurred in the last 40 years due to rapid deforestation followed by agricultural development and urbanization.

In a review of a soon to be published report on "Historical nutrient usage in coastal Queensland river catchments adjacent to the Great Barrier Reef Marine Park" (Reef Research, 1995), it is mentioned that presently, of the 80-85,000 tonnes/annum of N fertilizer applied, only 20-30,000 tonnes/annum are contained in the products sold from the farm. For phosphorus, these figures are 13,000 and 1-2,000 tonnes/annum respectively. The differences between these figures represent the potential losses of nutrients to the water, air, and soil of the environment, subject to local conditions.

Based on a overall plant nutrient balance for China (Agné, 1993), it can be concluded that the average nitrogen uptake efficiency in 1987 in China was approximately 35%, hence the potential loss is approximately 65% of the nitrogen supplied. The national inventory of Vietnam also mentions that in the Red River watershed, with an average annual fertilizer supply of 450 kg/ha N, 180 kg/ha P, and 90 kg/ha K, an estimated 30 to 40% of this amount is absorbed by the plants and 60 to 70% is potentially lost, especially with respect to nitrogen. At present, a sizable portion of the fertilizers applied in China and Vietnam are of organic nature, and these will be less mobile in the short-term. Therefore, the potential losses cannot be directly translated into real losses. From the long-term perspective, both these countries will probably shift more to using inorganic fertilizers. This may result in an increased level of loss of nutrients into the environment.

Other potential sources of nutrients that are highlighted in the national inventories are:

- Intensive livestock breeding
- Domestic sewage
- Industrial wastewaters

Although the WHO rapid assessment methodology (Economopoulos, 1993) contains some basic data on the magnitude of nutrients that are related to the above mentioned activities, it has not yet been possible, to quantify these sources of nutrients in the national inventories.

iii. Pollutants

Most of the participating countries (excluding Australia and Singapore) report that a significant part of their industrial wastewaters and domestic sewage is still being discharged into surface waters without receiving prior treatment. In those cases where the national inventories make mention of wastewater treatment facilities, their capacity is commonly expressed as the wastewater volume handled per day, and does not refer to their capacity to remove a certain quantity of organic pollution (which is to be considered as the prime objective of such facilities). Also, little or no information has been presented on the penetration of sewer systems, septic tanks, public/private latrines etc. into urban and rural areas.

In some inventories, the data presented give an insight into the estimated magnitude of the organic pollution load (expressed in Biological Oxygen Demand (BOD)) that is discharged into the estuary, bay, or coastal zone. Unfortunately, in most cases, such emissions cannot be traced back to quantified sources of origin and therefore, do not allow for targeted management or mitigation measures to be planned. Regarding toxic chemicals, there is only a limited amount of data available on the actual concentrations of heavy metals, PCBs, and pesticides. This is mainly because such measurements are complicated and rather costly to execute. For a number of these data, it is reported that the values detected are below certain standards, applicable to the waterbody concerned, but in many instances, these concentrations are given without reference to specific water quality standards. The only exception to the above overview on toxic chemicals is the reported river pollution in a number of countries by heavy metals due to uncontrolled dumping of mine tailings.

With respect to pesticides, most countries mention that the use and the volume of these chemicals has increased substantially over the past decade(s), but information on the actual rates of application in relation to specific crops is difficult to obtain from existing data. Although in a number of countries, efforts are being undertaken to restrict (or even ban) the use of very persistent pesticides, such measures are in some cases undermined by the illegal trade of these restricted/banned toxic chemicals (which are not included in official records).

4.2.3 Management and Mitigation Measures

All participating countries mentioned the need for an increased level of coordination between the national organizations involved in the assessment of the multitude of interlinked issues that are related to effective implementation of integrated watersheds management. Some countries advocate the establishment of special watershed-based organizations to undertake such coordinating/integrating tasks.

Such organizations, if given adequate legislative support, might eventually develop into watershed authorities that could implement the necessary action plans to mitigate the negative impacts of land-based sources of pollution within the watershed itself as well as in the coastal and marine environment.

The most obvious mitigation measures that can be undertaken to reduce riverine SNP loads are those that either reduce the land-based sources of SNP, or prevent the SNP loads from reaching the rivers, or both. Measures to reduce the sources are:

The reduction and eventual elimination of:

- Deforestation of natural forests
- Slash and burn agricultural practices
- Overgrazing of pasture lands
- Uncontrolled construction sites
- Uncontrolled open mining activities

With respect to preventing SNP loads from reaching the rivers, the following measures can be applied:

- Reforestation programmes
- Soil conservation practices in agriculture
- Slope protection measures for construction sites
- Improved nutrient balance/uptake by crops
- Better crop management practices
- Integrated pest management practices
- Clean technologies in industry
- Recycling in industries and households
- Construction of wastewater treatment facilities
- Impoundment of mine tailings
- Trapping of sediments in upstream riverbeds
- Absorbing nutrients in riparian vegetation
- Tertiary treatment of wastewaters

4.3 NEEDS

4.3.1 Knowledge

The most significant problem that the participating countries experienced during the preparation of their national inventories was the scattered nature of the data bases which they had to work from. Most of these data bases contain information that has been collected within the limited scope/perspective of the study/organization concerned. As the time, location, and sometimes the method of data collection differs between the various data sets, it is rather difficult to arrive at a composite, substantive data set on the complex issues related to watershed management and coastal and marine protection.

As such, there is a need to fill the following gaps in knowledge:

- Data on the magnitude and location of potential land-based sources of SNP;
- Data on the cause-effect relationships between:
  - (a) land-use patterns, soil erosion, intermediate storage of sediments, and riverine sediment loads; and
  - (b) soil characteristics, nutrient utilization/crop uptake, potential nutrient losses, and emissions of nutrients into rivers.
- Data on the magnitude and temporal distribution of riverine SNP loads; and
- Data on the estuarine and near shore coastal mechanisms/processes that convert riverine SNP loads into SNP impacts on the coastal and marine environment.

4.3.2 Management

Given the fact that in most of the participating countries, the management of the various resources within a watershed are subject to a compartmentalized approach within the respective but limited mandates and/or strategies of each agency concerned, the result is often that only sub-optimal solutions are arrived at. This problem can be further aggravated in situations where a number of administrative levels of government appear to have overlapping mandates/responsibilities. This apparent gap in coordination needs to be filled by an appropriate management option, subject to country specific conditions. Such an (interim) solution may eventually lead to the formation of a watershed authority.

4.3.3 Policy

Many of the participating countries face the problem of having a number of sectoral laws that relate to the use of resources on land and thus also relate to the resources in watersheds. As these sectoral laws are often implemented/enforced at the sub-national level, most watersheds come under the jurisdiction of more than one administrative unit, as well as under more than one national ministry/department. In addition, in a number of cases, the laws are reported to be outdated and becoming very complex due to piecemeal legislative amendments and complicated regulatory processes associated with their implementation. Also, taxes related to use of resources and fines related to non-compliance with certain regulations are not adjusted to inflation. This in turn can result in inadequate resources for effective law enforcement due to scarcity of manpower, equipment, and operational budget.

4.4 CONCLUSIONS

- Given the complex nature of integrated watershed management, there is a need to clearly define the objectives and types and levels of integration related to inter-territorial, inter-departmental, inter-disciplinary, and inter-ecosystem issues.
- Apart from the Mekong River, and possibly the Red River, there appear to be no other major river systems in the EAS region with a need for an international integrated approach to watershed development.
- The major cause of higher riverine sediment loads in the EAS region is increased levels of soil erosion, which in turn are due to:

(a) disruption of the natural vegetation; and
(b) application of unsound agricultural practices.

In some instances, the uncontrolled dumping of mine tailings adds to the increase of riverine sediment loads.

- The present agricultural practices in most of the EAS countries can give rise to considerable levels of potential nutrient loss to the environment. This is mainly due to a substantial increase in the application of inorganic fertilizers and incomplete nutrient uptake by the crops.

- In the EAS region, most domestic sewage and industrial wastewaters are still being discharged into open waters with little or no prior treatment. In quite a number of cases, these pollution loads exceed the self purification capacity of the waterbodies and result in a de-oxygenation of the water with negative impacts on the environment.

- Heavy metals, PCBs, and persistent pesticides are a major concern for riverine, coastal, and marine ecosystems because bio-accumulation of these substances gives rise to environmental and ecotoxicological impacts, including significant health risks to humans. Although, the participating countries share these concerns, relatively few data are presently available on either the sources of toxic chemicals or on their riverine discharges into the coastal area.

4.5 RECOMMENDATIONS

- There is a need for an integrated approach to the implementation of the mitigation measures to reduce riverine SNP loads. These measures cover a wide range of activities listed above, and require a holistic and integrated approach across different territories, departments, disciplines, and ecosystems. The success of integrated watershed management will depend greatly on the political will and commitment to establish well-defined coordination mechanisms and arrangements to undertake such challenging tasks. Moreover, to be effective, integrated watershed plans need to be incorporated into overall national development plans.

- There is a need for a (further) quantified assessment of the land-based sources of sediments, nutrients, toxic chemicals, and organic pollutants, to the extent that the location and (relative) magnitude of each of these sources can be established in sufficient detail to allow for the preparation of a targeted plan of action to reduce the land-based sources of SNP and their related impacts on the coastal and marine environments.

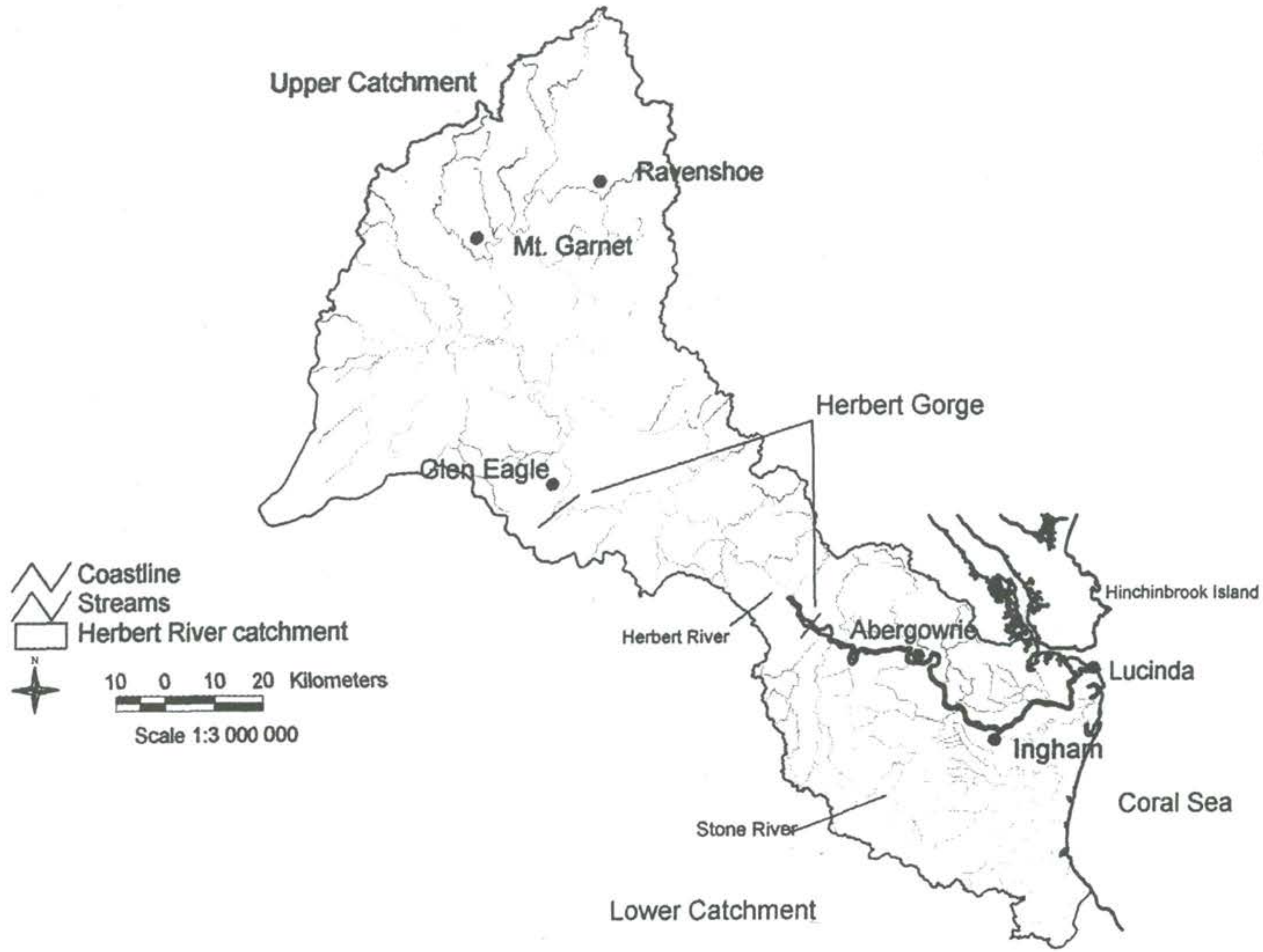
4.6 SYNOPSES OF COUNTRY INVENTORIES

4.6.1 Australia

1. Herbert River watershed

The Herbert River watershed (see Figure 4.1), which is typical for a number of watersheds in the wet tropical coast of north-eastern Australia, drains an area of approximately 10,000 km^2 to the Coral Sea and contains the largest river in that region. Widely differing rainfall regimes are characteristic of the watershed, and rainfall is strongly influenced by the incidence of cyclonic activity in the November to May period. Approximately 75% of the mean annual rainfall occurs from December to March. Evaporation exceeds medium rainfall from May to November.

Figure 4.1 The Herbert River watershed.



Source: Johnson and Bramley, 1995

Large areas of the watershed remain under natural vegetation. These vegetation communities are closely related to rainfall, soil types, and in particular, the drainage attributes of those soils. In the coastal lowland area, however, about 35 to 40% of the land has been cleared for crop production or improved pastures. In terms of arable agricultural production, the sugar industry is dominant with approximately 55,000 ha of land. Significant areas in both the upper and lower watershed are devoted to plantation forestry, with approximately 21,500ha planned to be under exotic pines in the lower watershed. Fertilizers (N and P) are required. Herbicides are applied to reduce competition from weed growth. Pineapples are also an important crop in the lower Herbert. This crop requires significant inputs of fertilizer, pesticides, and water. Beef cattle in the watershed are grazed mainly on native pastures, but extensive pasture improvements have occurred in the lower watershed area. The latter improvements require nutrient applications because phosphorus deficiency is widespread on the alluvial soils.

The Herbert watershed, being a rural watershed, has limited urban development in the lower Herbert and in the northeast corner of the upper watershed. In 1993, approximately 18,000 people resided in the watershed, of which 75% were located in the lower watershed. Industrial development is limited and focuses on sugar and saw mills in the lower watershed and saw mills and tin mining in the upper watershed.

2. Information on water flow and sources of pollution

The mean annual run-off of the Herbert River watershed is 493 mm, which represents 37% of the average annual precipitation. The mean annual flow of the river is 3,440 million m^3, with a maximum recorded flow of nearly 12,000 m^3/s (1967) and a minimum of 0.24 m^3/s (1919). The highest monthly discharges occur from November to May, with flash floods being a recurrent phenomenon in the Herbert River.

Over geological time, the Herbert River has eroded the table land escarpment to form its gorge. Eroded material has been transported downstream and sediment has been deposited to form the Herbert Delta. The estimated sediment budget for the Herbert watershed is thought to be approximately 2 million tonnes of sediment passing through the mouth of the river, with an estimated 90% originating from the gorge and the upper watershed, and 10% from below the gorge.

Sediment input into the river could have been increased by the clearing and cultivation of land for sugar cane, boatwash in the lower reaches, grazing and damage to riverbanks by livestock, grazing and cropping in the upper watershed, and the impact of extensive mining in the upper watershed area. There are no data to substantiate these observations. However, the adoption of green cane harvesting - minimum tillage (now used in 99% of cane farms) has resulted in a decreasing sediment supply to the river. Also, improved land management in the grazing areas, and the stabilization of mining sediments in the upper watershed are part of the strategy to manage sedimentation in the Herbert River.

The major point sources of pollution are the outfall of the 5,000 m^3/d Ingham sewage treatment plant (mainly nitrogen and phosphorus); the effluents from the two sugar mills (possibly alcohols and sugars); drainage (agricultural chemicals, hydrocarbons, nutrients); sand and gravel extraction from water courses (hydrocarbons); and mining activities (possible source of heavy metals). There are no data to substantiate the magnitude of these point sources, but some observations have been made on the concentrations of soluble nitrogen and orthophosphate in the river.

In the Herbert River system, diffuse source pollution has the greatest potential to generate water quality problems. The major potential sources and the types of pollutants generated are summarized below in Table 4.5.

Table 4.5 **Potential diffused sources and types of pollutants for the Herbert River watershed.**

Diffuse sources	Sediments	Nutrients	Herbicides Pesticides	Hydro-carbons	Particulates
Land clearing	X	X			X
Agriculture & grazing	X	X	X	X	X
Burning-off & wildfires	X	X			X
Urban & on-farm development	X	X		X	X
Stormwater run-off	X	X	X	X	X
River recreation		X		X	

Source: Kirkman, 1995

4.6.2 Cambodia

1. General characteristics at the country level

Cambodia is a country covering an area of just over 180,000 km^2. The most recent data on land-use in Cambodia are presented below in Table 4.6.

Table 4.6 **Land-use in Cambodia.**

Type of Land Cover	Area (km^2)
Forest	112,842
Other vegetation	25,057
Urban areas	45
Paddy fields	26,097
Receding rice fields	293
Upland crops	4,665
Swidden agriculture	1,856
Orchards	188
Plantation	746
Field crops	5,299
Water surfaces	4,111
Barren lands	336

Source: Mekong Secretariat; data acquired during the dry season 1992-1993 for the UNDP/FAO/ADB Cambodia Agriculture Development Options Review.

Topographically, the country can be divided into three distinct parts : (i) the central plains with a large portion having an elevation of less than 10 m + MSL; (ii) the mountain ranges and high plateau, surrounding the central plains; and (iii) the flat coastal areas. The central plains, which form three quarters of the country, mainly consist of the alluvial floodplains of the Mekong River and also include the Tonle Sap Basin. The flat coastal areas to the southwest, bordering the Gulf of Thailand, are a hydrological unit separate from the Mekong drainage basin.

The climate of Cambodia is tropical monsoon, with a distinct southwest monsoon rainy season from May to early October, and a dry season from November to April that is associated with the northeast monsoon. Rainfall in the central area averages between 1,200 to 1,900 mm/yr, and increases toward the east to between 1,800 and 3,000 mm/yr.

2. Coastal region watersheds

At present, there is relatively little information available on watersheds in Cambodia, outside of the Mekong watershed. The total drainage area of the coastal region covers approximately 10% of the land area of Cambodia (see Figure 4.2). The hydrological characteristics of the drainage basins of the seven major rivers in the coastal region of Cambodia, with respect to their average annual precipitation and their estimated average annual run-off, are given below in Table 4.7:

Table 4.7 Cambodia watersheds and their run-off

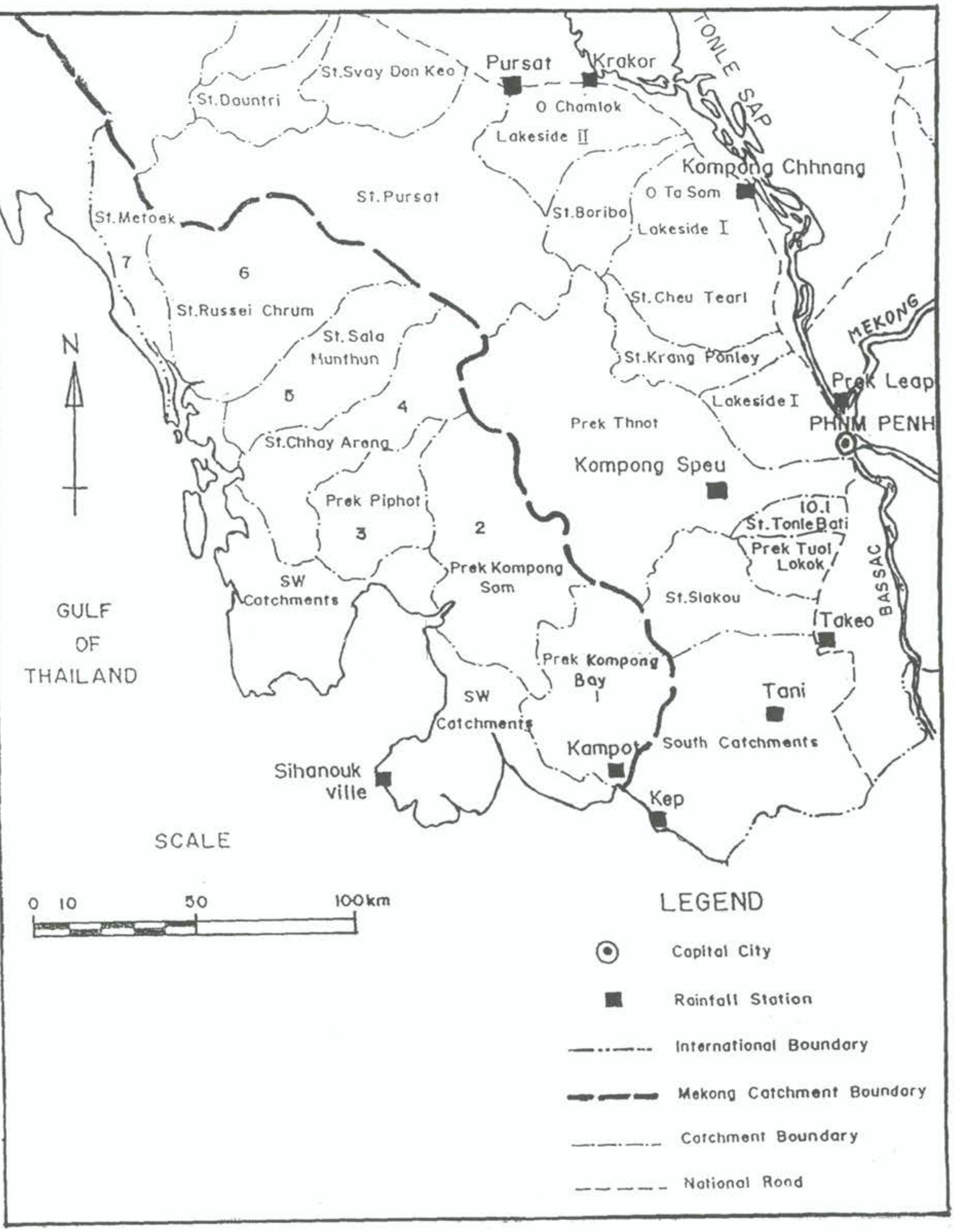
Watershed	Precipitation mm/year	Average run-off	
		mm/year	m^3/s
Prek Kampong Bay	2,077	1,177	77
Prek Kampong Som	2,214	1,311	110
Prek Piphot	3,032	2,114	78
Stung Chhay Areng	2,873	1,959	131
Stung Sala Munthum	2,783	1,870	93
Stung Russei Chrum	2,665	1,754	152
Stung Metoek	3,305	2,382	86

Source: Ponlok, 1995

The volume of flow of these relatively short rivers is extremely variable depending on the season. At present, these rivers do not play an important role in Cambodia's economy, but they do have a certain potential for the development of hydroelectric power.

The land cover of these coastal watersheds (1994 data) is dominated by forest (90%), and only about 7% of the land area reported to be used for agricultural purposes. The mangrove forests cover approximately 2% of the coastal watersheds.

Figure 4.2 Coastal watersheds of Cambodia.



Source: Ponlok, 1995

3. Sources of nutrients, toxic chemicals, and organic pollutants

Cambodia's coastal areas have been relatively undisturbed up until the current decade. At present, however, impacts on the coastal and marine environment are becoming considerably more serious because of the changes in the political climate, population and economic growth, and business influences from neighboring countries. A number of economic activities such as logging, intensive shrimp farms, charcoal production, and commercial fishing are having an increasing impact on the coastal and marine environment.

The major land-based sources of nutrients, toxic chemicals, and organic material are: domestic sewage, solid waste, agro-industrial waste, and toxic chemical waste from provincial capitals, fishing villages, and the above mentioned economic activities in relevant areas. All coastal cities and villages presently lack sewage treatment systems. The common method of sewage disposal is direct discharge into the rivers or into the sea. To date, other land-based activities like agriculture, construction of coastal infrastructure, tourism, and mining do not contribute much to coastal and marine pollution due to their underdevelopment. At the same time, intensive shrimp culture, charcoal production, and logging are having a relatively serious impact on coastal and marine environments.

4.6.3 China

1. General characteristics at the country level

In view of the vast area of the People's Republic of China, and keeping in mind the main objectives of the EAS project, the "country level" summary of the general characteristics is limited to the main rivers that flow into the southern part of the East China Sea and into the South China Sea. From north to south the following four main river systems are encountered:

- The Changjiang River system

  The Changjiang River, with its total length of over 6,000 km and its drainage basin of over 1.8 million km^2, is the largest river in China. The river flows into the East China Sea near Shanghai.

- The Qiantangjiang River system

  The Qiantangjiang River, the largest river in Zhejiang Province, runs through the Hangzhou Bay into the East China Sea.

- The Minjiang River system

  This is the largest river in Fujian Province and also flows into the East China Sea.

- The Zhujiang River system (Pearl River system)

  The watershed of the Pearl River has a complex river system consisting of the Xi Jiang (West River), the Dong Jiang (East River), and the Bei Jiang (North River). These three rivers join each other in the Pearl River Delta and flow southwards through a number of branches into the South China Sea, just west of Hong Kong.

Some of the characteristics of these river basins are presented below in Table 4.8:

Table 4.8 Characteristics of Chinese river basins

Name of river	Catchment area (km^2)	Length (km)	Annual run-off (10^9 m^3)	Average flow (m^3/s)
Changjiang	1,808,500	6,300	980	31,060
Qiantangjiang	54,394	494	47	1,480
Minjiang	60,992	577	62	1,980
Zhujiang	453,100	2,216	335	10,620

Source: Hongbang, Zheren, Zhangyuan, Shuying, and Yanmin, 1995

The sources of wastewater discharge are recorded at the provincial level, and in Table 4.9, these provincial data are arranged in accordance with the four main river basins, as cited above.

Table 4.9 Sources of wastewater (1993) 10^6 m^3/a

River system	Province	(a)	(b)	(c)	(d)
Changjiang	Shanghai	2,032	1,281	982	144
	Jiangsu	2,974	2,116	1,941	5
	Anhui	1,271	870	755	4
	Jiangxi	1,048	707	571	-
	Hubei	2,742	1,413	1,136	10
	Hunan	1,816	1,554	1,111	4
	Sichuan	2,919	1,582	1,347	22
	Guizhou	409	259	196	-
	Total	15,211	9,782	7,949	189
Qiantangjiang	Zhejiang	1,718	1,057	896	46
Minjiang	Fujian	943	573	508	21
Zhujiang (Pearl River)	Guangdong	2,960	1.398	1,023	26
	Guangxi	1,445	932	784	8
	Total	**4,405**	**2,330**	**1,807**	**34**

Source: Hongbang, Zheren, Zhangyuan, Shuying, and Yanmin, 1995

(a) = total wastewater discharge
(b) = total industrial wastewater
(c) = direct discharge into surface water
(d) = indirect discharge into surface water from wastewater treatment facilities

A similar presentation has been prepared in Table 4.10 with respect to heavy metals and phenols that are contained in the industrial wastewaters.

Table 4.10 Pollutants in industrial wastewater (ton/annum)

Province/River	Hg	Cd	Cr(6+)	Pb	As	Phenol
Chiangjiang						
Shanghai	0.01	0.08	10.04	2.24	8.76	106.50
Jiangsu	0.05	0.50	34.22	7.38	77.57	415.73
Anhui	0.29	4.77	28.07	29.86	106.22	204.18
Jiangxi	0.08	6.38	8.77	119.87	27.92	245.40
Hubei	0.03	0.26	18.40	12.29	21.84	214.02
Hunan	4.33	27.46	38.13	421.50	152.68	334.26
Sichuan	0.72	1.59	37.12	9.96	10.85	269.33
Guizhou	0.03	0.08	2.28	6.39	9.22	121.00
Total	**5.54**	**41.12**	**177.03**	**609.49**	**415.06**	**1,910.42**
Qiantangjiang						
Zhejiang	**0.20**	**0.56**	**25.19**	**18.90**	**7.89**	**108.03**
Total	**0.20**	**0.56**	**25.19**	**18.90**	**7.89**	**108.03**
Minjiang						
Fujian	**0.18**	**1.87**	**2.57**	**12.09**	**4.59**	**76.92**
Total	**0.18**	**1.87**	**2.57**	**12.09**	**4.59**	**76.92**
Zhujiang (Pearl)						
Guangdong	0.17	2.86	35.59	61.70	25.91	75.69
Guangxi	0.32	24.87	0.01	117.82	50.10	77.53
Total	**0.49**	**27.73**	**44.60**	**179.52**	**76.01**	**153.22**

Source: Hongbang, Zheren, Zhangyuan, Shuying, and Yanmin, 1995

2. Pearl River watershed

The Zhujiang or Pearl River (see Figure 4.3) has been selected as the watershed to be studied because, firstly, the economic development and urbanization in this watershed - and particularly in the Pearl River Delta - has been very rapid during the past 15 years (and is expected continue to be so), and, secondly, the Pearl River empties into the South China Sea in an area where coastal and marine ecosystems are sufficiently abundant to study the possible environmental impacts of land-based sources of pollution on the status of these ecosystems. The river characteristics of the Pearl River system are summarized below in table 4.11:

Table 4.11 Pearl River characteristics

Name of river	Catchment area (km^2)	% of total	Annual run-off (10^9 m^3)	% of total
West River	352,700	78	230	69
North River	46,700	10	51	15
East River	27,000	6	26	7.5
Delta	26,700	6	28	8.5
Total	**453,100**	**100**	**335**	**100**

Source: Hongbang, Zheren, Zhangyuan, Shuying, and Yanmin, 1995

The total population in the Pearl River basin based on data from the 1990 census exceeds 90 million, with the delta being the most densely populated area, accounting for approximately 18% of the population on only 6% of the watershed area. The population distribution in the East and North river basins is proportionate to their respective shares in the land area and encompasses 6% and 10% of the total population respectively. The largest portion of the population (66% or 60 million people) live in the West Pearl River basin. Within the entire watershed, over 80% of the population is considered to be rural.

From the land-use patterns, which are summarized in Table 4.12, it can be concluded that: (i) the delta area is more intensively used for agriculture than the three river basins; (ii) forest cover is still relatively high in the North and East river basins; and (iii) that about one quarter of the land area of the West River Basin is categorized as barren land.

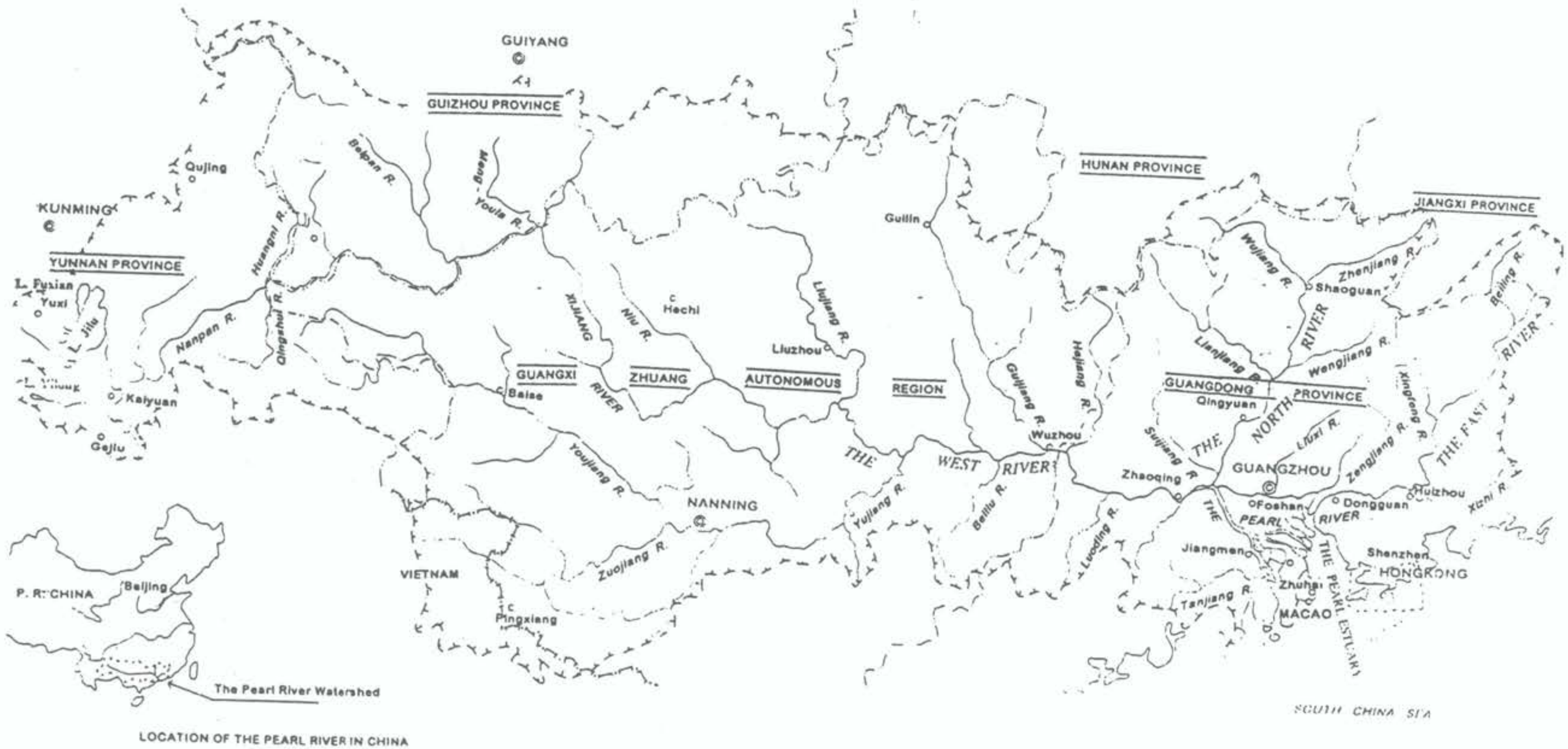
Table 4.12 Land-use patterns in Pearl River watershed *

Basin	Agriculture		Forest		Barren	
	km^2	%	km^2	%	km^2	%
West	33,360	9.8	83,750	24.6	84,330	24.7
North	4,240	9.1	22,030	47.2	5,490	11.8
East	2,650	9.3	14,120	52.7	3,190	11.8
Delta	6,320	23.6	6,490	24.7	2,850	10.6
Total	**46,570**	**10.5**	**126,390**	**28.6**	**95,870**	**21.7**

*Within PRC only excluding 11,170 km^2 in Vietnam
Source: Hongbang, Zheren, Zhangyuan, Shuying, and Yanmin, 1995

Soil erosion in the Pearl River watershed is reported to be a serious problem. Statistics from 1991 mention 1,757 km^2 of eroded land in the East River basin (5.7% of the catchment area) and 53,328 km^2 of eroded land in the West River basin (15.1% of the catchment area). In the Zhenjiang River, one of the tributaries of the North River, the riverbed rose over 5 meters during the period 1937 - 1980 due to eroded soils.

Figure 4.3 The Pearl River watershed.



Source: Hongbang, Zheren, Zhangyuan, Shuying, and Yanmin, 1995

3. **Information on water flow and sources of pollution**

There is adequate information available on the spatial and temporal distribution of rainfall and evaporation within the watershed, which together provide a relatively complete understanding of the spatial distribution of net precipitation and run-off depth. These data can be used to check the measurements of water discharge from the various sub-drainage basins of the Pearl River watershed.

The Pearl River is reported to discharge a significant quantity of suspended sediments into the delta area, and subsequently into the sea. Detailed information on the spatial variation of suspended load concentration is available. When multiplied by the annual water discharges, the total sediment input by the West, North and East rivers into the delta is estimated at about 90 million tons/yr., of which about 20% is deposited in the delta area, and about 80% is discharged into the South China Sea.

The average amount of chemical fertilizers used in the Pearl River watershed is reported to be as high as 750 kg/ha/yr., and for some areas even higher figures can be derived from the available data if total amounts of chemical fertilizers are divided by total areas of agricultural land. As these data may refer to the total weight of all fertilizers together, they may not reflect the specific amounts of nitrogen, phosphorus, and potassium.

With respect to the heavy metals, Table 4.10 gives a first indication of the magnitude of the heavy metal load in the Pearl River but does not include information on the types and locations of its sources. The use of pesticides in the watershed in 1979 was reported to be 60,000 tons of organic chlorine insecticides. Recent (1989) statistics mention figures of 13,000 tons/yr. and 8,800 tons/yr. for pesticide use for the West and East river basins respectively. This may reflect the impact of the ban which was introduced in China in 1980 on the use of highly toxic and long-time residual insecticides and pesticides.

It is reported that the total BOD load of the Pearl River discharged into the South China Sea is around 1,740 tons/day in the flood season and 720 tons/day in the dry season, averaging 1,230 tons/day. The magnitude of this BOD load is the equivalent of the daily pollution load generated by approximately 25 million people.

4.6.4 Indonesia

1. <u>General characteristics at country level</u>

Indonesia consists of thousands of islands, with some islands having many rivers. In order to guarantee the protection of its water resources, the Government of Indonesia has divided the country into 90 river basin development units. One of these development units is the Ciliwung-Cisadane River Basin Development Unit (CCRBDU) which is located in the Jabotabek area on West Java. This area has been selected as the Study Site because it contains all the rivers which discharge into the Bay of Jakarta.

2. <u>Ciliwung-Cisadane River Basin</u>

The Ciliwung - Cisadane River Basin Development Project covers two administrative units (i.e., the West Java Province and Jakarta Capital City) and contains a total of thirteen different rivers. These rivers are from west to east: Cidurian, Cimanceuri, Cirarab, Cisadane, Angke, Pesanggrahan, Grogol, Krukut, Ciliwung, Cipinang, Cakung, Bekasi, and Cikarang. From the available maps (see Figure 4.4), the total surface area of the CCRBOU watershed is estimated to be about 6,000 km^2. The largest river, draining about 20% of the total watershed, is the Cisadane, followed by the Bekasi, Ciliwung and Cidurian rivers. These four rivers are also the main sources of water for the irrigation schemes in the Jabotabek area.

The total population in the Jabotabek area was about 14 million people in 1985. This figure is projected to increase to about 23 million by the year 2005. Due to rapid urbanization, the rural population is expected to drop from 35% of the total population in 1985 to less than 25% of that in 2005. Based on the agricultural ecosystem map of 1993, the land-use in the Cisadane River watershed (1,184 km^2) was 22% forests; 13% plantations; 4% single crop paddy fields; 38% multiple crop paddy fields; 16% dry fields; 6% residential areas; and 1% fishponds.

3. Information on water flow and sources of pollution

One of the major concerns in the Jabotabek area is flood control for Jakarta City. This is accomplished by intercepting the rivers flowing towards Jakarta in flood diversion canals and diverting them towards the east and the west of the City. A second point of focus is the irrigation of paddy fields which requires diversion of river water from the four main rivers as mentioned before. The inventory refers to data from the Hydrology Year Book of the Research Institute for Water Resources Development (RIWRD), and it is expected that sufficient data on monthly flows and daily flows can be made available when calculations of volumes of sediments, nutrients, and pollutants need to be made.

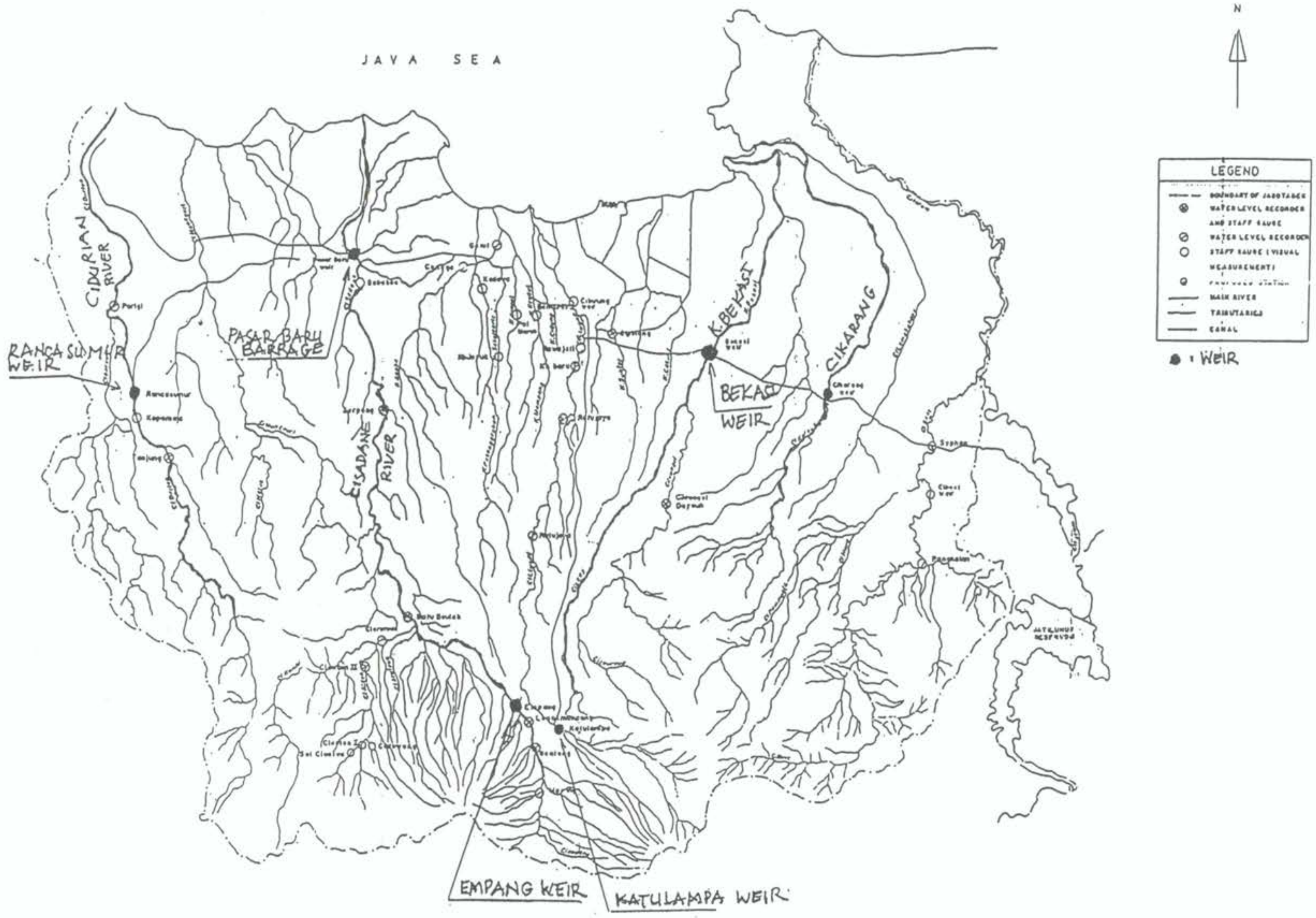
With respect to industrial pollution sources, an inventory was made of all industries within the Cisadane River basin. After analysis, it appeared that among the 84 industries listed there were 56 industries that could potentially pollute the river. Using a rapid assessment methodology similar to that of the WHO, the BOD, Chemical Oxygen Demand (COD), Suspended Solids (SS), toxicity, ammonia, organic nitrogen, phosphate, organic phosphorous, coliform, and hydrocarbon loads for each of these industries were calculated. These net industrial pollution loads were corrected with a specific abatement coefficient to take into account any purification processes used before the effluents were discharged into the river basin. The results of this study are presented in Table 4.13.

Table 4.13 Relative balance of industrial net pollution loads in Cisadane River

Sub-basin	BOD loads kg/day	%	COD loads kg/day	%	Toxic loads kg/day	%	SS loads kg/day	%
Serpong	3,528	77.4	6,431	78.1	19,650	66.9	3,475	69.0
Tangerong	784	17.3	1,451	17.6	9,721	33.0	1,449	28.7
Bogor	219	4.8	302	3.7	10	0.1	61	1.2
Others	24	0.5	44	0.6	0	0.1	53	1.1
Total	**4,555**	**100**	**8,228**	**100**	**29,381**	**100**	**100**	**100**

Source: Uktolseya and Wibowo, 1995

Figure 4.4 **The drainage basin into Jakarta Bay.**



Source: EAS-35 Second Workshop, 1995

For the determination of domestic and agricultural sources of pollutants, the parameters assessed were: BOD, COD, ammonia, Total Suspended Solids (TSS), and coliform. The magnitude of the net pollution loads is based on the number of people that discharge directly or indirectly into the river, the per capita pollution production ratios, and reduction coefficients with respect to retention and partial sedimentation in drains, wastewater treatment facilities, or other mechanism. In order to arrive at reliable data, a validation study was carried to calibrate the production ratios per capita in urban settings as well as in rural areas. For the urban settlements, a survey was carried out to determine the penetration of septic tanks and pit-latrines. Using the data from these surveys, the total balance of domestic pollution loads, as BOD, in the Cisadane River basin can be calculated, as is shown in Table 4.14. It appears that, for the Cisadane River basin, domestic pollution accounts for approximately 70% of the total BOD load and the industrial pollution for only 30% of load. With respect to pollution loads due to agricultural activities (*i.e.*, the use of chemical fertilizers and pesticides, the application of manure, and the wastes from stock breeding), no data on these loads were reported in the inventory.

Table 4.14 Balance of domestic pollution loads for BOD in Cisadane river basin

Main cities	Settlement[1]	Population 1990	Raw BOD loads (kg/day)	% raw	Net BOD loads	% Net
Tangerang	SP	9,364	281	0.6	46	0.4
	P	126,285	5,552	12.3	3,866	34.9
Total	SP+P	135,649	5,833	12.9	3,912	35.3
Serpong	SP	5,009	150	0.3	26	0.2
	P	3,102	140	0.3	116	1.0
Total	SP+P	8,111	290	0.6	142	1.2
Bogor	SP	15,317	460	1.0	96	0.9
	P	83,006	3,813	8.4	3,241	29.3
Total	SP+P	98,323	4,273	9.4	3,337	30.2
Rural	R	1,502,000	34,877	77.1	3,679	33.3
TOTAL			**45,272**	**100**	**11,070**	**100**

Source: Uktolseya and Wibowo, 1995

4.6.5 Republic of Korea

1. <u>General information at country level</u>

Korea is a rugged country, covered by about 70% mountainous terrain. The land surface of the western part of Korea has a gentle slope and is traversed by high sinuous meandering rivers. These rivers, having complicated dendritic drainage patterns, flow westward and southward into the sea. In contrast, east of the dividing mountain range a number of short rivers which run steeply into the sea. The climate in the southern part of Korea is temperate. Mean annual

[1] SP = Semi permanent settlement
P = Permanent settlement
R = Rural settlement

precipitation is 1,159 mm of which 50% is concentrated in the summer monsoon period of July and August.

With respect to the five main rivers in Korea (*i.e.*, the Kum River, the Yongsan River, the Naktong River, the Somjin River, and the Man-gyong River - see Figure 4.5), their major characteristics have been summarized in Table 4.15. The watersheds of the Kum River and the Yongsan River have been selected for the more detailed watershed inventory because of the rapid industrialization that is taking place in the western part of Korea.

Table 4.15 Major River Systems in the Republic of Korea

Main stream	Watershed (km^2)	Annual precipitation (mm)	Mean flow (m^3/s)	Population (1,000)	Pollutants discharge BOD (kg/day)
Kum River	9,886	1,206.8	73.6	3,068	334,352
Yongsan River	2,861	1,386.9	15.4	1,906	126,375
Naktong River	23,860	1,079.0	102.0	6,548	716,969
Somjin River	2,143	1,287.2	26.9	572	91,392
Man-gyong River	1,602	1,404.1	11.0	963	94,733

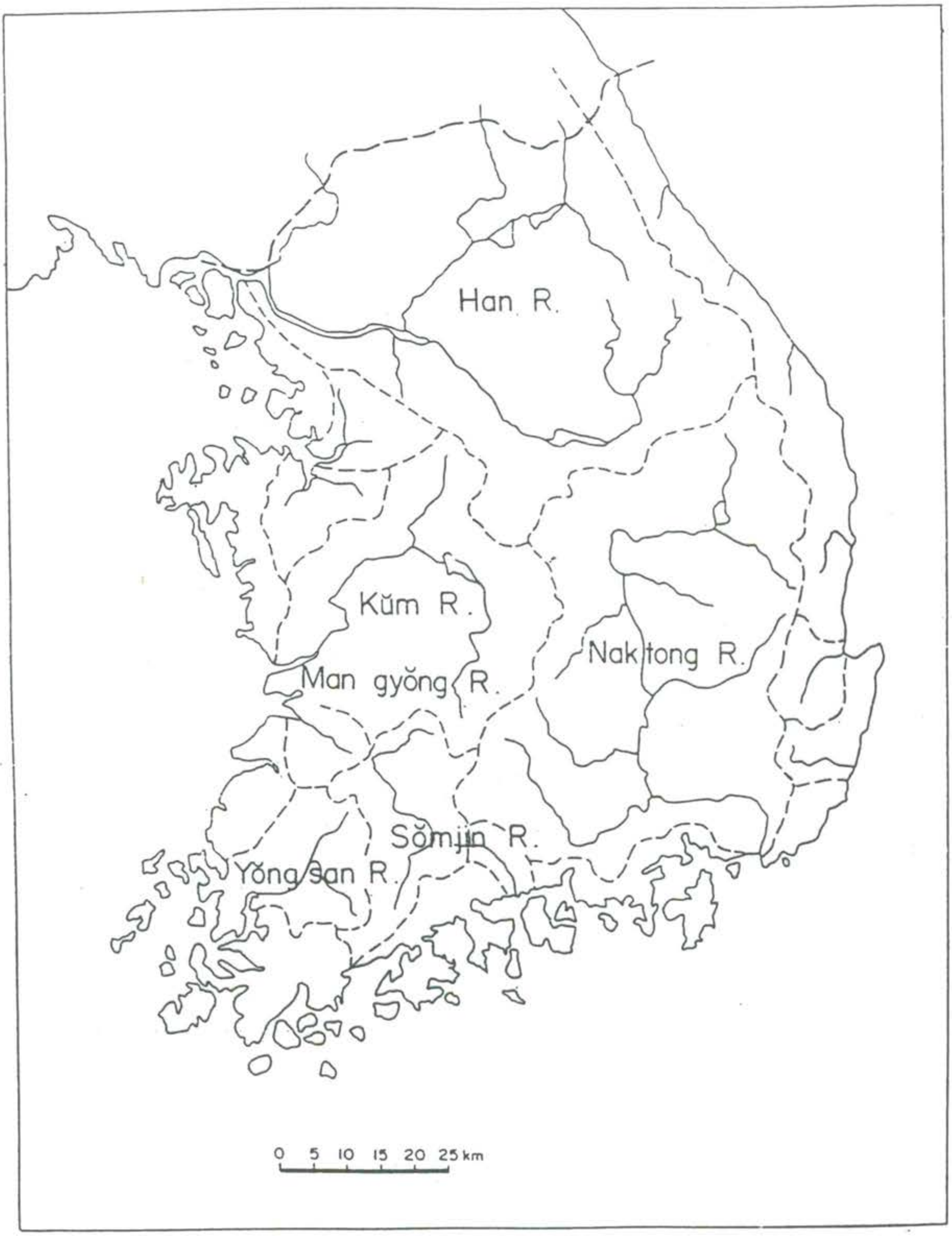
Source: Korea Ocean Research and Development Institute, 1995

2. Kum River and Yongsan River watersheds

The surface area of the drainage basin of the Kum River represents about 15% of the total land area of the Republic of Korea. With respect to its vegetation cover, only data at provincial level are available indicating approximately 30% cultivated land and 55% cover by forests. Of the agricultural land-use, data are available at the county level (there are 25 counties within the Kum River watershed). These data indicate that 90% of the agricultural land is used for paddy fields, 5% for dry fields, 4% for orchards, and 1% for pastures. The approximate aggregate figures from county level data on livestock farming are : 250,000 beef cattle, 50,000 dairy cows, and over 600,000 pigs within the Kum River basin. Fish farms are reported to cover about 800 ha. Of the total population of over 3 million people, about 55% are living in urban areas.

The surface area of the drainage basin of the Yongsan River represents approximately 4% of the total area of the country. Provincial level data on vegetation are more or less identical to those for the Kum River basin. The county level data on agriculture reveal the following data: 91% paddy field, 4% dry field, 3.5% orchard, and 1.5% pasture. In regard to livestock farming, the figures are: 100,000 beef cattle, 23,000 dairy cows, and 200,000 pigs. Aquaculture is also mentioned, covering approximately 1,250 hectares. Of the estimated 1.75 million inhabitants in the Yongsan River watershed, over 65% are living in urban areas. By the year 2001, the population in this area is expected to increase to 2.1 million inhabitants.

Figure 4.5 Major river systems of the Republic of Korea.



Source: Korea Ocean Research and Development Institute, 1995

3. Information on water flow and source of pollution

There is detailed information available on annual and monthly precipitation and on the balance of water resources in the major river basins of Korea. Records of water levels and discharge rating curves for a number of cross sections make it possible to arrive at an overview of water flows in the main rivers and their tributaries.

The major source of suspended solids is eroded soils. Recent observations indicate the TSS contents in the downstream part of the Kum River is between 30 and 40 mg/l. In the mid-course of the river, TSS levels of 30 mg/l are reported. These data, however, are not correlated with water discharges, and therefore no data on volumes of sediments are presently available. In addition, there are a number of reservoirs in the Kum River, and these may have a significant impact on sediment loads.

There are country level figures available on the production and consumption of chemical fertilizers. The use of chemical fertilizers in the respective river basins is estimated by multiplying the ratio between the surface area of the watershed and that of Korea, by the total production of fertilizers. There are no data available on the use of natural fertilizers. In Table 4.16, some data on nutrient contents of the five main rivers are presented.

Table 4.16 Nutrient Contents at mid-stream

Main stream	COD (mg/l)	Ammonia (μg/l)	TKN* (μg/l)	Phosphate (μg/l)	Nitrate (μg/l)
Naktong R.	2.1 - 8.3	60 - 1946	1066 - 6246	8 - 141	207 - 1133
Kum R.	1.7 - 4.4	89 - 282	1771 - 2500	14 - 51	723 - 2351
Yongsan R.	4.7 - 20.1	151 - 4975	1578 - 6964	33 - 542	316 - 1099
Sonjin R.	1.6 - 6.3	79 - 108	394 - 632	11 - 38	281 - 646
Man-gyong R.	1.1 - 23.8	14 - 1037	1938 - 2211	13 - 50	387 - 2767

*TKN = Total Kjeldahl Nitrogen
Source: Korea Ocean Research and Development Institute, 1995

Toxic chemicals are routinely investigated in the river waters. Contents of Cd, Pb, Cr (6+), As, Hg, Cu and CN are monitored, but in most cases not detected. With respect to pesticides, the 1992 level of total consumption was about 27,000 tons/yr. Using the same pro rata method as mentioned above for the nutrients, an estimate of the watershed-level consumption of pesticides was prepared.

The information on organic pollutants consists of scattered data sets at the provincial level, but not for particular watersheds. Nevertheless, initial data have been collected on the number and size of existing treatment facilities for industrial wastewater as well as for domestic sewage. It is estimated that about half the combined volume of the domestic and industrial wastewater is receiving some type of treatment before its discharge into the surface waters.

4.6.6 Malaysia

1. Introduction

The main emphasis of the inventory of Malaysia focuses on the country's experience with the development of water quality criteria and water quality standards in relation to the beneficial uses of river waters.

2. Water quality criteria and standards

An extensive survey of river water quality in Malaysia was initiated by the Department of Environment (DOE) in 1985. Its purpose was to develop water quality criteria and standards that take into consideration the beneficial uses of river water for (i) domestic water supply; (ii) fisheries and aquatic life; (iii) recreation; (iv) livestock watering; and (v) agricultural use. The so-called DOE/WQS project was completed in 1994. It resulted in a division of rivers into classes of beneficial uses in descending order of water quality. The 16 major rivers included in the DOE/WQS project are indicated in Table 4.17, with their respective catchment areas and number of DOE monitoring stations (see also Figures 4.6a, 4.6b, 4.6c) for those located on Peninsular Malaysia.

Table 4.17 River basins classified under DOE/WQS project

Basin no.	River name	Catchment area (km^2)	No. DOE stations
1	Perlis	653	8
5	Muda	3,793	8
6	Prai/Juru	560	13
13	Perak	14,642	37
14	Bernam	2,674	7
16	Selangor	1,820	6
18	Kelang	1,212	22
21	Linggi	1,306	15
22	Melaka	746	8
25	Muar	6,062	32
33	Rompin	4,009	20
35	Pahang	43,670	65
43	Terengganu	11,415	7
48	Kelantan	11,474	31
51	Sarawak	3,398	11
83	Sugut	3,094	8
Totals	**16 rivers**	**110,533 km^2**	**298 stations**

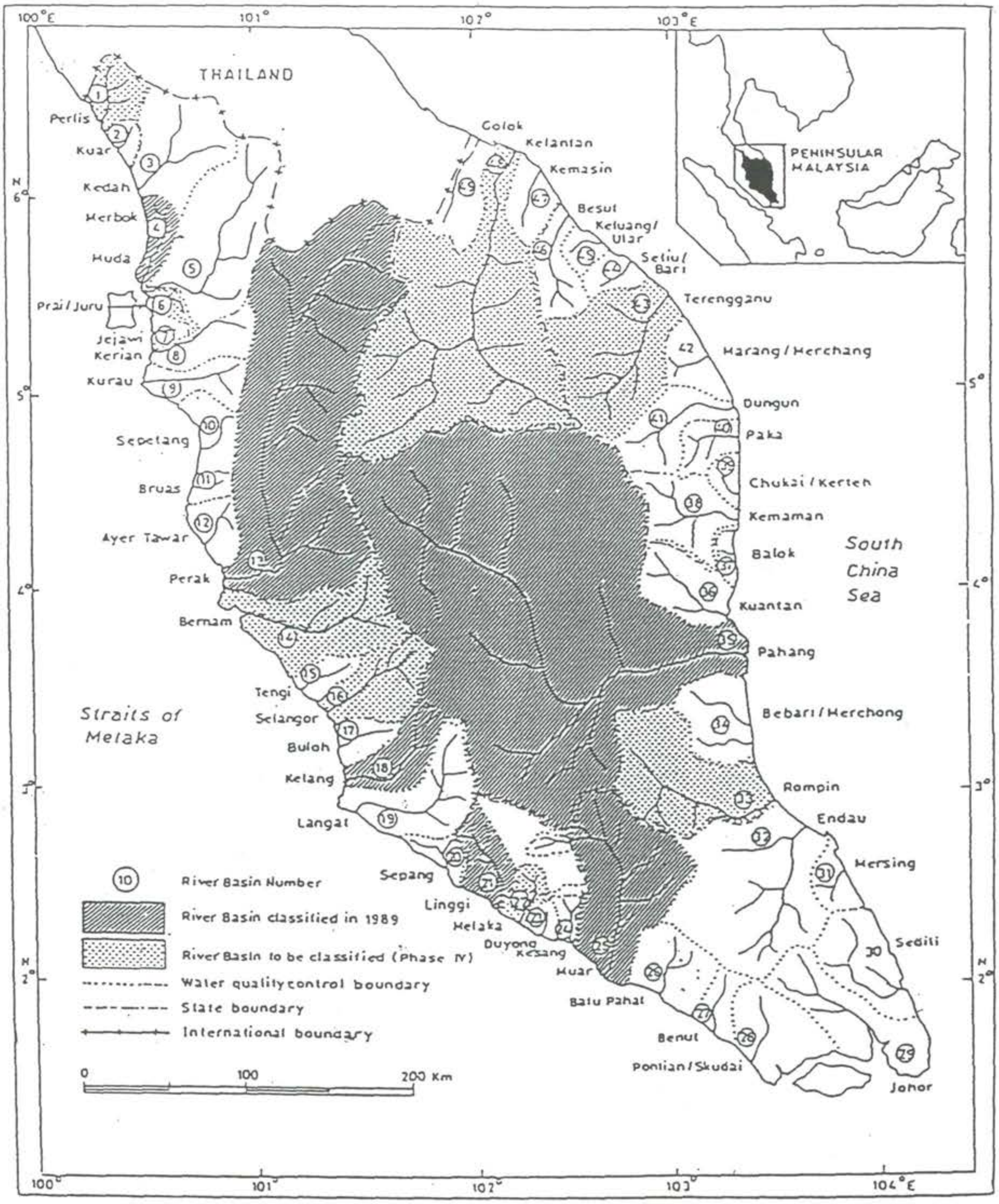
Source: Bujang, 1995

In addition to the classification of rivers, one of the other objectives of the DOE/WQS project was the development of a River Basin Management Information System (RBMIS). This RBMIS consists of the following six major modules:

i. Water Quality Data base Module
ii. Pollution Sources Module
iii. Aquatic Ecology Module
iv. Flow and Catchment Module
v. Land-use Data Module
vi. Socio-economic Module

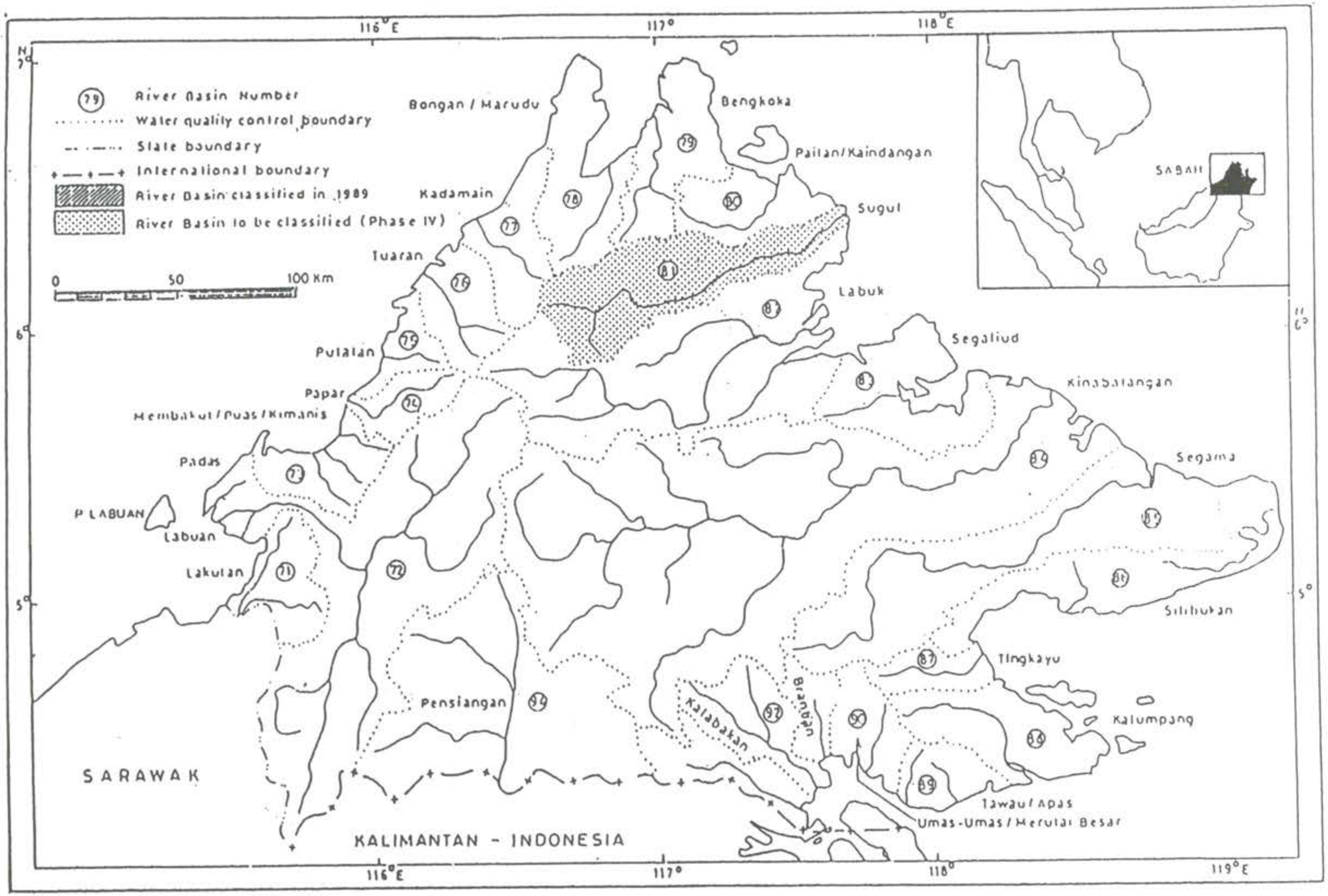
In the water quality database, the observed parameters are listed under four groups: (i) general water quality (*i.e.*, DO, COD, BOD, TSS, NH_4 - N, NO_3 -N, PO_4 -P, pH, conductivity, salinity, and turbidity (NTU)); (ii) microbiological water quality (*i.e.*, total coliform and fecal coliform); (iii) trace metals (*i.e.*, Al, As, Bo, Cd, Ca, Cr, Cu, Fe, Lb, Mg, Hg, Se and Zn); (iv) others (*i.e.*, Cl, oil, grease, detergents and phenols, and organochlorines in some basins only).

Figure 4.6a River basin quality control regions in Peninsular Malaysia.



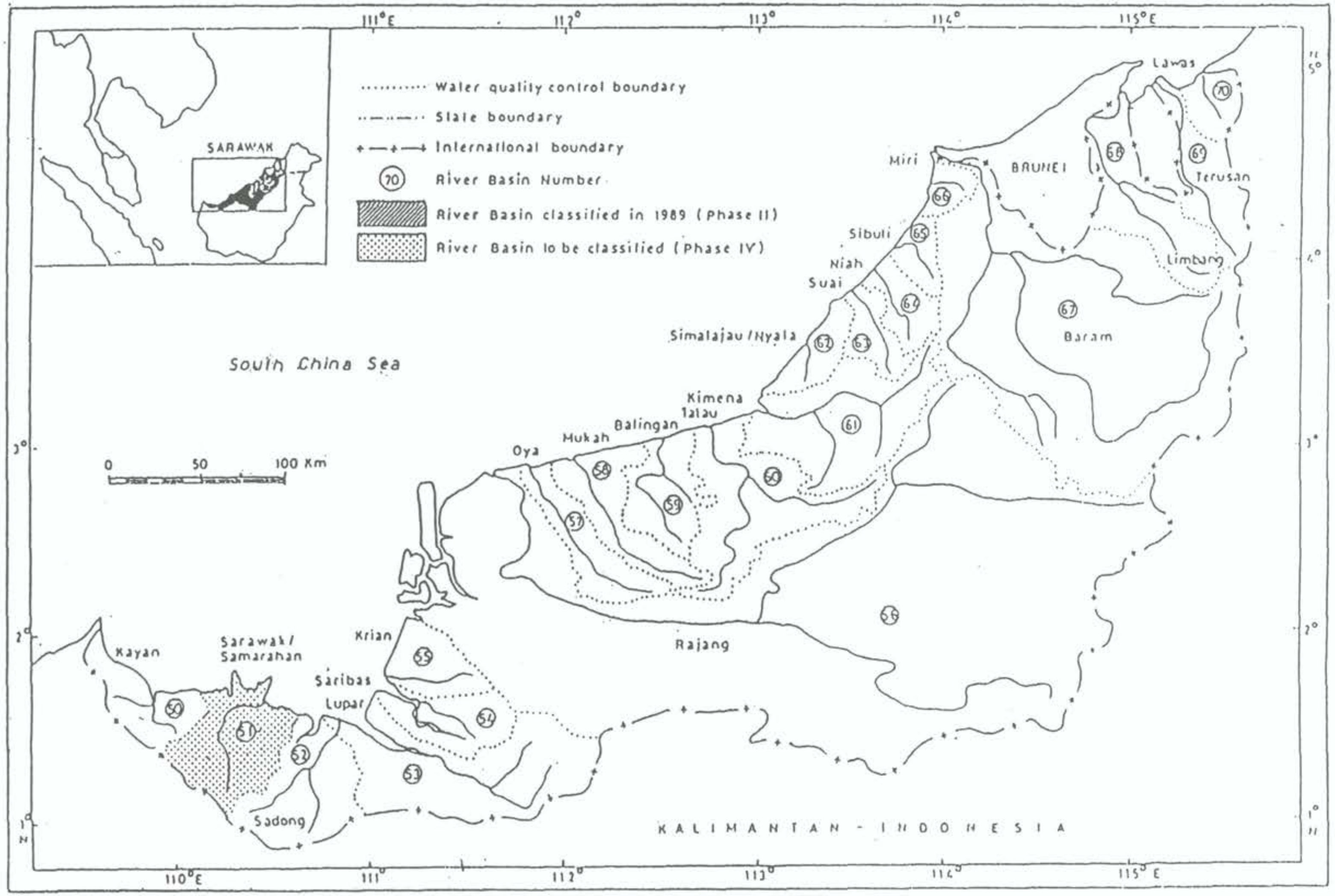
Source: Bujang, 1995

Figure 4.6b River basin quality control regions in Sabah, Malaysia.



Source: Bujang, 1995

Figure 4.6c River basin quality control regions in Sarawak, Malaysia.



Source: Bujang, 1995

In the pollution sources module, the pollution sources are divided into two groups: (i) palm oil and rubber industries for which the type of disposal, volume, and quality of effluent are available both from quarterly reports of industries and periodic monitoring by DOE, and (ii) other manufacturing industries, animal husbandry, sewage works, and others for which only listings of location, type, head counts, and production data are available.

With respect to the aquatic ecology inventory, it was concluded that biological parameters should reflect the abundance and diversity of species at various trophic levels. It appeared that for the biological community, adequate quantitative data was primarily limited to phytoplankton/periphyton.

For the flow and catchment module, most hydrological data were made available from the data base of the Drainage and Irrigation Department with additional information from the Public Works Department and the Water Supply Department. Together, these data are said to provide a good overall understanding of the surface water hydrology of the river basins.

In the land-use and socio-economic module, population data and growth rates are given (or estimated) and the socio-economic status of each of the river basins is reviewed in terms of economic activities (water uses related to the socio-economic development are indicated).

The present inventory of watersheds by Malaysia does not include substantive data that could be derived from the above cited River Basin Management Information System, but refers to more detailed information in the respective reports published under the DOE/WQS project for each of the 16 river basins as listed in Table 4.17.

4.6.7 The Philippines

1. General characteristics at country level

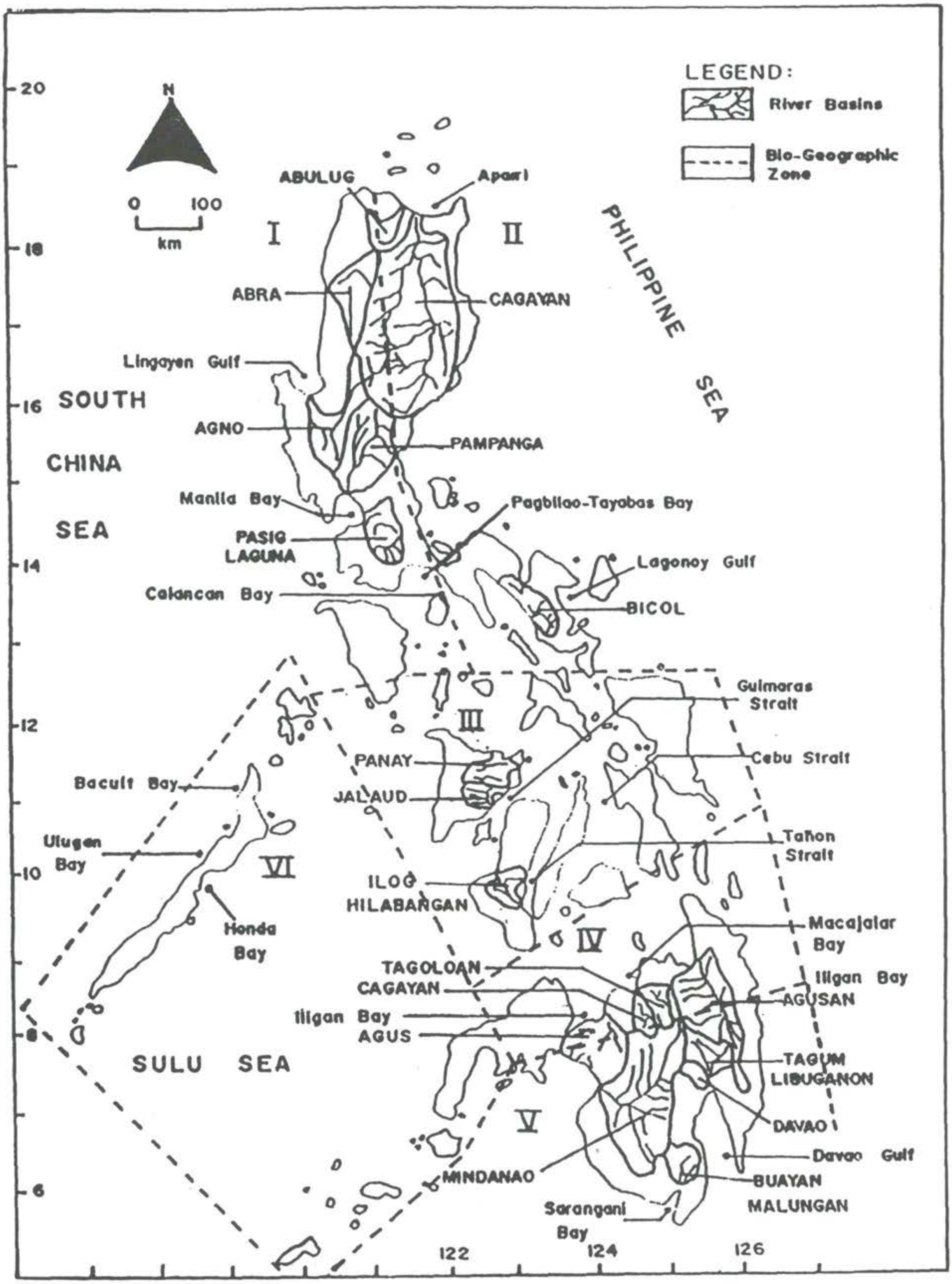
The total land area of the Philippines, (300,000 km^2), is subdivided into 421 river basins, which are classified as 18 principal river basins and 403 minor river basins. A principal river basin is defined as having a drainage basin of the least 1,400 km^2. See Figure 4.7.

Among these 18 principal river basins, the Agno River basin is considered to be representative of the actual situation in the Philippines with respect to the environmental stresses that are the result of over-exploitation of forests and other natural resources, and improper land-uses. In the past, excessive logging operations and shifting cultivation were very common. These and other destructive land-based activities have consequently caused rapid rainstorm run-off and accelerated soil erosion.

2. Agno River watershed

The total land area of the Agno River basin is 15,122 km^2 and thus represents approximately 5% of the Philippines' total land area. The Upper Agno River, having a drainage area of 1,245 km^2, is essential for the socio-economic development of the Cordillera Region as source of water to the adjacent regions and lowland areas. The Ambuklao and Binga dams in Benguet Province depend on the upper Agno River water discharges to generate hydroelectric power for northern and central Luzon including Metro Manila. These dams also provide irrigation water for the agricultural needs in Pangasinan Province.

Figure 4.7 River basins within the biogeographic zones of the Philippines.



Source: Alonzo-Pasicolan, 1995

The Lower Agno River basin, comprising large portions of Pangasinan, Tarlao and Zambales provinces, covers 13,877 km^2, and consists of numerous small rivers, draining the vast alluvial plains of northern Luzon into the Lingayen Gulf. The land-use patterns in the Upper and Lower Agno basins are summarized below in Table 4.18.

Table 4.18 Land-use in Agno River Basin

Land-use	Upper Agno Basin (1,245 km^2)	Lower Agno Basin (13,877 km^2)
Forest	41%	3%
Brushland	24%	26%
Agriculture	31%	57%
Settlements	4%	
Grasslands	-	6%
Idle lands	-	4%
Wetlands	-	2%
Other lands	-	2%

Source: Alonzo-Pasicolan, 1995

3. Information on water flow and sources of pollution

In the Agno River basin, the rainy season is from May to October, and August generally has the most precipitation. Over the Upper Agno River basin, the average annual precipitation during the past 10 years was 3,400 mm, but varied between 460 and 8,000 mm. The average annual rainfall over the Lower Agno River basin was about 2,200 mm.

The river discharge in the Ambuklao and Binga rivers in the Upper Agno River basin varies between 282 m^3/s in the dry season to 91,000 m^3/s during the rainy season. The Ambuklao and Binga reservoirs have surface areas of 390 and 470 km^2 respectively and support two hydroelectric plants. The downstream discharge of these reservoirs is greatly influenced by the operation of these plants. In the Lower Agno River basin, few data except some dry weather flows, are available on water discharges.

A major source of concern with respect to sediments is the mining industry in the Upper Agno River basin, comprised of three gold mines, two copper mines, and two limestone quarries. Open pit mining produces large amounts of sediment - with suspended solids concentrations in the mine tailing ranging between 32,400 and 85,800 mg/l. When the river water is distributed to irrigation systems in the Lower Agno basin, it still has between 87 and 15,100 mg/l. This results in silts and fine sands being deposited in irrigation canals and paddy fields. The daily discharge of mine tailings is estimated to be more than 25,000 tons/day. No data are given on sediment loads carried by the Lower Agno River towards the coastline.

Although the Lower Agno basin includes a significant area of agricultural land, no data are given on levels of chemical and natural fertilizers applied. Also, no reference is made to observations on water quality parameters in the Lower Agno River.

Apart from the high concentrations of cyanide in the mine tailings - ranging between 1 and 30 mg/l - which result in cyanide levels in the downstream irrigation water of between 1 and 2 mg/l, no other data on toxic chemicals or the amounts of pesticides used are referred to in the inventory.

It is reported as a common observation that most municipalities in the Upper Agno River basin discharge untreated or under-treated domestic sewage into the rivers, and heavily polluted stretches of river affect the quality of irrigation water. The Province of Pangasinan in the Lower Agno River basin is relatively more industrialized compared to other provinces in the neighboring regions. The inventory lists the type of industries, but does not substantiate the volume of their activities nor their potential pollution loads.

4.6.8 Singapore

1. General characteristics

Singapore consists of the main island of Singapore and some 58 islets within its territorial waters. The main island is about 580.6 km^2 in area. It has a coastline of approximately 150 km. The total land area, including the islets, is 639.1 km^2. Of this, more than 40 km^2 is from foreshore reclamation. See Figure 4.8. Singapore has a moderately low relief, with more than 60% of the land surface below 30 m in elevation and only 10% above 100 m.

The climate of Singapore is classified as a hot and wet equatorial type with high average temperatures, humidity, and rainfall throughout the year, with no distinct seasons. Precipitation is high, with mean rainfall ranging from 2,000 mm along the south coast to 2300 mm in the north central areas.

Singapore today is a highly urbanized and developed country. The demands imposed by an increasing population, changing lifestyles, and an ever expanding economy have resulted in a chronic shortage of land. This has placed great pressure on the island's limited resources, both inland and coastal, and has prompted the relevant authorities to utilize these resources in an intensive fashion.

There are a total of 40 drainage basins in Singapore, the largest of which drains 68.12 km^2. Due to the island's small size, there are no extensive river systems, and none serve as sources of potable water. However, over the past decade, several rivers along the western coast and one in the east were dammed to create reservoirs to receive and store freshwater for domestic, commercial, and industrial uses.

The land-use pattern has changed drastically over the past 30 years (Table 4.19). The rapid increase in built-up areas has almost doubled, and now accounts for about half of the total land area. The use of land for economically less valuable industries like farming have given way to uses which provide higher economic returns. From 1965 to 1985, there was an almost 300% reduction in farm holding areas. The changing land-use patterns and land-based activities in Singapore over the past 30 years have resulted in a change in the nature and types of pollution discharged into the various rivers and reservoirs.

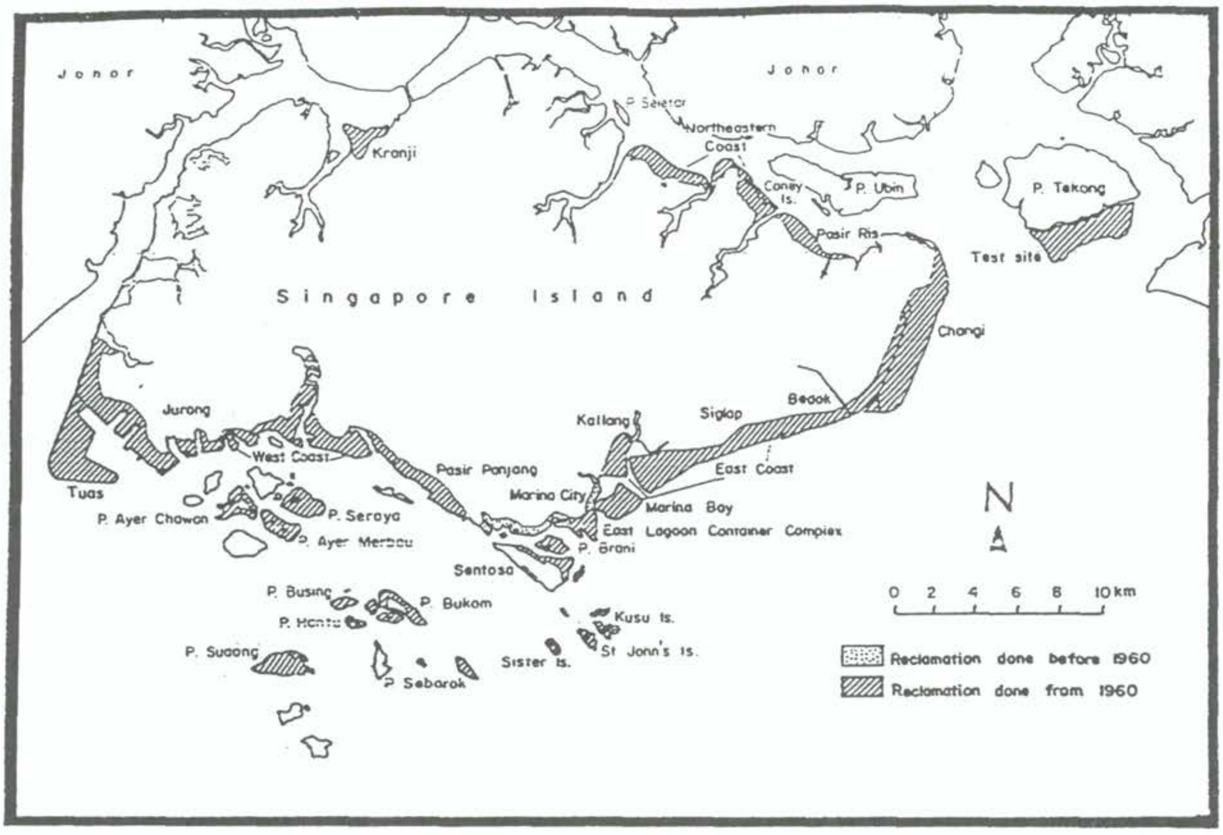
Table 4.19 Land-use patterns in Singapore between 1965 to 1985 (in km^2)

Year	Total	Built-up area	Farm area	Cultivated* area	Forest	Marsh & tidal	Others
1965	581.5	177.4	131.6	110.1	35.0	35.0	92.4
1970	586.4	189.9	134.0	95.8	32.4	32.4	101.9
1975	596.8	228.4	105.9	95.8	32.4	32.4	101.9
1980	617.8	275.1	80.9	95.0	30.0	26.0	110.8
1985	620.5	298.8	47.1	*	28.6	18.5	227.5
1992	639.1	312.4	6.8	*	28.6	15.7	275.7

* Included under 'others' from 1981

Source: Department of Statistics (1965-1992)

Figure 4.8 Map of Singapore showing the extent of foreshore reclamation.



Source: Singapore Department of Statistics, 1992

During the 1960s and 1970s, most of the rivers in Singapore were highly polluted. The waters were stagnant, dirty, and foul-smelling. The many industries lining the rivers discharged their effluents (solid waste and wastewater) directly into the water and there was little or no control of such discharges from industrial, commercial, domestic, and agricultural sources. In 1977, the government initiated a massive clean-up programme to rid the rivers, especially those in the Singapore River and Kallang basins, of the filth and stench that characterized them. The programme, coordinated by the Ministry of the Environment and involving various other ministries, organizations, and the general public, took almost 10 years to complete. The success of the clean-up is evident from the pollution and stench-free waters of the rivers, recorded improvements in water quality, and the re-establishment of benthic and pelagic aquatic life.

2. Information on land-based sources of pollution

The Strategic Planning and Research Department (SRPD) regularly monitors the water quality of various inland water bodies and coastal areas. A total of 47 streams in water catchment areas, 17 rivers and streams in non-water catchment areas, and 19 sampling points in the coastal area are monitored. The Public Utilities Board also monitors the water quality of 13 reservoirs. Parameters analyzed include pH, DO, BOD, TSS, ammonia, and sulfide. In addition, a total of 129 United States Environmental Protection Agency priority pollutants, which include chloroform, benzene, toulene, trichloromethane, pyrene and chlordane, are monitored yearly in the water catchment areas.

Horticulture and animal husbandry, especially pig farming, were identified as important sources of water pollution. The need to control pollution from such sources became more urgent following the construction of reservoirs and dams across the mouth of many major rivers in Singapore. Since 1979, pig farming activities have been relocated from the water catchment areas and urban river systems to more rural areas like Punggol, with the ultimate aim of completely phasing out pig farming.

The population of Singapore is well-served by an efficient network of underground sewers, pumping stations, and six major sewage treatment plants. Today, about 96% of Singapore's population is provided with modern sanitation facilities. Effluent is conveyed to sewage treatment works before it is finally discharged into the sea. Industrial effluents that meet the stipulated discharge limits are also permitted to be discharged into the sewers. Industrial effluents not discharged into the sewerage system are allowed to be discharged directly into drains and rivers only if they comply with the stringent discharge limits. Effluents from oil-based industries can be discharged directly into the sea after appropriate treatment, which involves the removal of oils and grease.

Treated domestic and industrial effluents contain between 5 and 10% of the original BOD and SS in the raw wastewater. This results in a treated effluent with a BOD of less than 20 mg/l and a TSS content of less than 30 mg/l. Not all treated effluents are discharged into the sea; about 2% undergoes advanced treatment to produce non-potable industrial water used for purposes such as cooling equipment, toilet flushing, and watering of roadside trees and golf courses.

4.6.9 Thailand

1. General characteristics at country level

The total land surface of Thailand amounts to about 515,000 km^2. The country has been divided by the National Water Resources Committee into 25 river basins on the basis of the topography of Thailand. See Figure 4.9.

The Chao Phraya River system, with its main tributaries the Ping River, Wang River, Yom River, Nan River, and Pasak River as well as its parallel downstream branch, Tha Chin River, has a watershed of over 150,000 km^2, and drains about 30% of the country's land area into the upper Gulf of Thailand. The northeastern part of Thailand belongs to the watershed of the Mekong River. This means that about 185,000 km^2, which is 35% of Thailand, drains through the Mekong River towards the South China Sea.

With respect to the remaining 35% of the land area, there are three rivers of some importance: (*i.e.*, the Mea Klong River, located in the west of central Thailand, with a drainage area of about 30,000 km^2; the Tapi-Phum Duang River basin in the south of Thailand having a drainage area of about 12,000 km^2; and the Bang Pakong River in the east of Thailand with a drainage basin of just over 8,000 km^2.

2. Tapi-Phum Duang River watershed

The national inventory of Thailand focuses on the Tapi-Phun Duang River basin, which covers less than 2.5% of the land surface area of Thailand. This river basin was selected because the area is the economic focal point of the future Southern Seaboard project of Thailand.

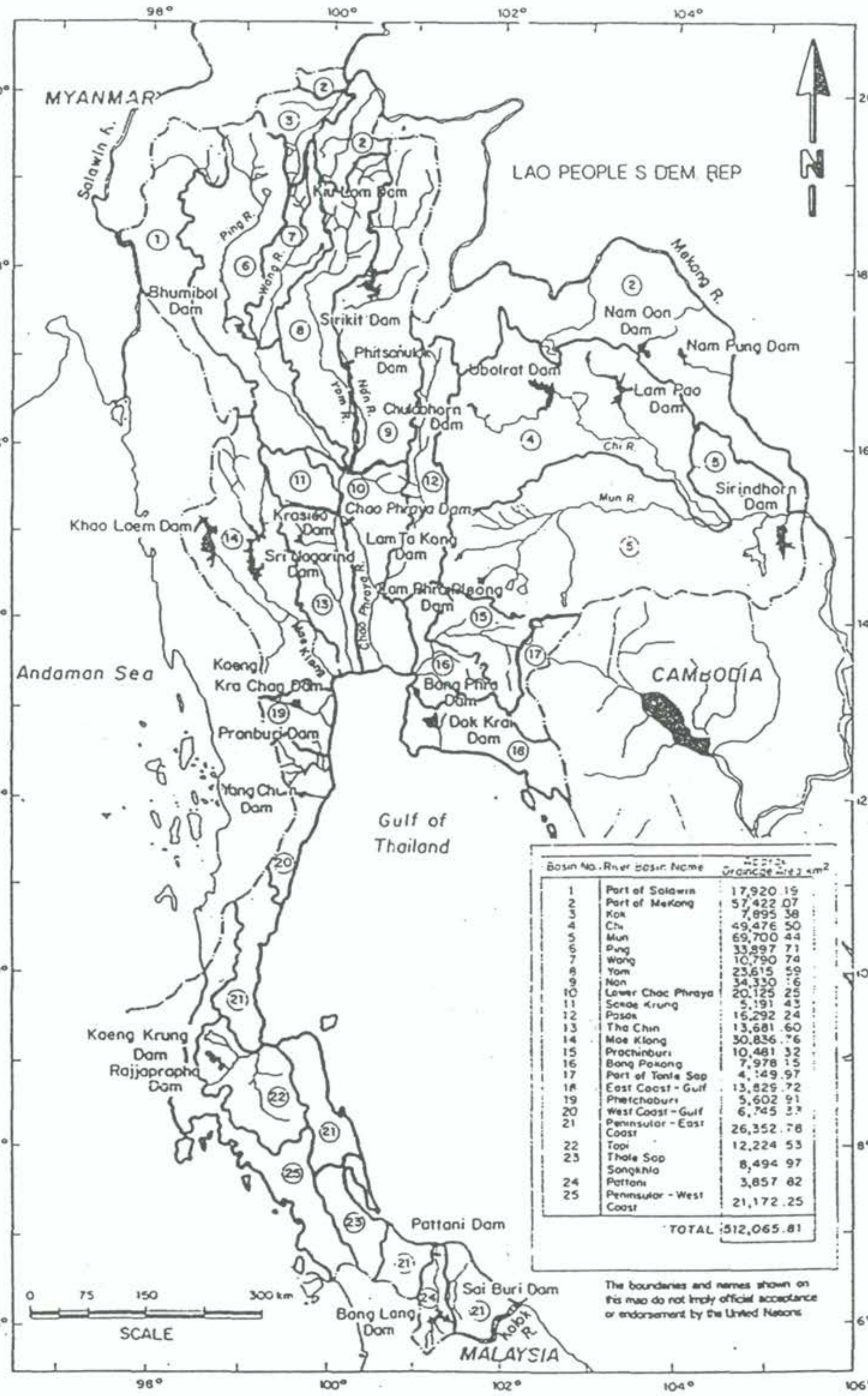
The Phum Duang River basin covers 6,125 km^2 and that of the Tapi 5,460 km^2. Both rivers form an extended delta as they discharge into Ban Don Bay in the Gulf of Thailand. See Figure 4.10. The average annual discharge of both rivers together amounts to about 10 x 10^9 m^3. The discharge of the Phum Duang River is mainly influenced by the Southwest monsoon, whereas the Tapi River has its maximum discharge during the Northeast monsoon period.

The Tapi-Phum Duang basin is covered mainly by agricultural production areas, about 65% of the total area, subdivided into: 23.5% rubber tree plantation; 14% rubber tree with forest land; 6.5% rubber tree plantation with pastures; 7.5% rubber tree plantation mixed with oil palm trees; 2.5% rice; and 11% other crops. About 30% of the watershed is covered by evergreen tropical rain forests. The region's population is concentrated mainly in Surat Thani, which presently has an estimated population of 875,000 inhabitants, of which about 85% are rural population.

3. Information on water flow and sources of pollution

The hydrological characteristics of the selected rivers are presented in Table 4.20, appear inconsistent. When the annual run-off is divided by the watershed area, the net run off varies between 537 and 5,162 mm/yr, against an annual rainfall in Surat Thani of 1,755 mm/yr.

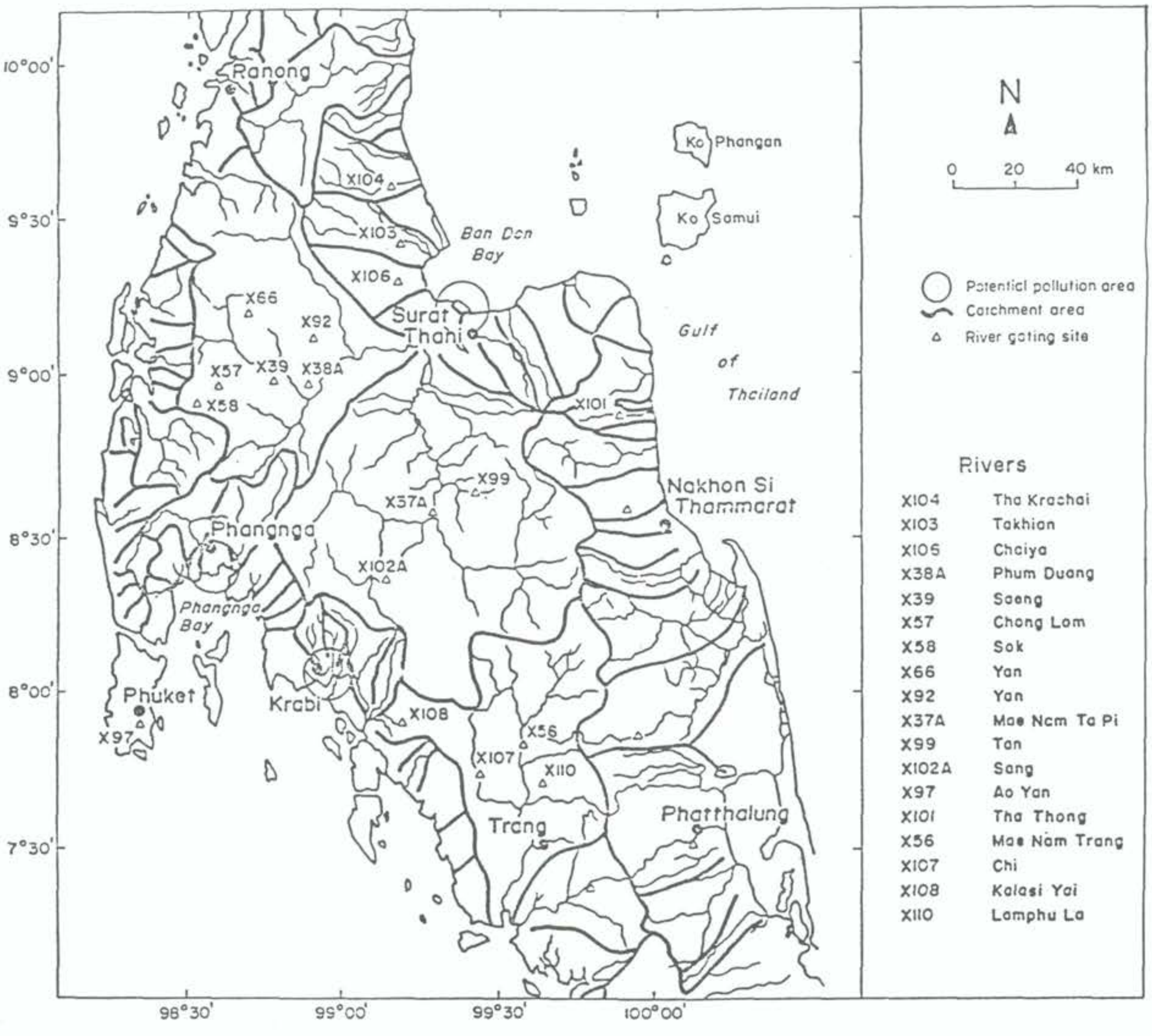
Figure 4.9 Map of river basins in Thailand.



Basin No.	River Basin Name	Drainage Area km²
1	Part of Salawin	17,920.19
2	Part of Mekong	57,422.07
3	Kok	7,895.38
4	Chi	49,476.50
5	Mun	69,700.44
6	Ping	33,897.71
7	Wang	10,790.74
8	Yom	23,615.59
9	Nan	34,330.[illegible]6
10	Lower Chao Phraya	20,125.25
11	Sakae Krung	5,191.43
12	Pasak	16,292.24
13	Tha Chin	13,681.60
14	Mae Klong	30,836.76
15	Prachinburi	10,481.32
16	Bang Pakong	7,978.15
17	Part of Tonle Sap	4,[illegible]49.97
18	East Coast - Gulf	13,829.72
19	Phetchaburi	5,602.91
20	West Coast - Gulf	6,745.[illegible]
21	Peninsular - East Coast	26,352.78
22	Tapi	12,224.53
23	Thale Sap Songkhla	8,494.97
24	Pattani	3,857.82
25	Peninsular - West Coast	21,172.25
	TOTAL	512,065.81

Source: Sanpanich, 1995

Figure 4.10 Map of Upper South river catchments in Thailand, including Ban Don Bay.



Source: Putchakarn, 1995

Table 4.20 Hydrological characteristics of the Tapi-Phum Duang Basin, 1984

No.	River	Watershed area (km^2)	Discharge (m^3/s)			Ratio Maximum/ minimum	Annual run-off (million m3)
			Mean	Minimum	Maximum		
X 38A	Phum Duang	2,706	179.60	5.70	1,686.60	296	5,679.3
X 39	Saeng	1,437	116.60	4.70	1,437.60	306	3,886.2
X 57	Chong Lom	8	1.31	0.11	22.66	206	41.3
X 58	Sok	312	26.36	2.00	250.05	125	833.7
X 66	Yan	661	36.00	1.80	561.00	312	1,138.3
X 92	Yan	1,001	44.24	5.00	473.00	95	1,399.0
X 37A	Ta Pi	5,200	131.92	16.50	421.60	26	4,171.5
X 99	Tan	105	1.78	0.28	14.08	51	56.4
X 102A	Sang	152	2.76	0.04	21.88	547	87.4

Source: ONEB, 1992

The information on sediment loads is limited and refers to (i) a site on the Tapi Phum Duang River which reflects only about 47% of the basin (station X 38A in Table 4.20) and (ii) a tributary of the Tapi Phun Duang River (station X 39). It is not clear how these data were derived on the basis of the stated recording period of 17 years.

No data have been presented on the use of chemical and/or natural fertilizers in the watershed, and data on water quality measurements only refer to observations in the saline estuary section of the Tapi River estuary in March and August 1987. During these observations in the Tapi estuary in 1987, the concentrations of dissolved trace metals (Hg, Cd, Cr, Cu, Pb and Zn) were also measured. On the basis of these measurements, it was concluded that there appears to be no significant heavy metal pollution in the estuarine section of the Tapi River.

With respect to organic pollution, the inventory focused on the situation around Ban Don Bay. No data have been presented on the watershed itself. The available data on Ban Don Bay describe the total generated load (TGL) and the actual discharged load (ADL). The ratio between TGL and ADL is determined by the number of sewer lines in the community and the level of treatment of industrial wastewaters.

4.6.10 Vietnam

1. General characteristics at country level

The territorial area of Vietnam covers about 300,000 km^2. The country has about 2,500 rivers and tributaries with a length of more than 10 km each. Along the coastline, there is on the average one river mouth almost every 20 km. Most of the rivers have catchment areas of less than 500 km^2. In Vietnam, there are only nine large river systems with catchment areas of more than 10,000 km^2. They are from north to south: Kycung-Bang Giang; Thai Binh; Hong (Red River); Ma; Ca; Thu Bon; Ba; Dong Nai; and Cuu Long (Mekong). The Kycung-Bang Giang River is the upstream tributary of the Pearl River, which flows northeastward towards Guangzhou in the PRC. The other eight main rivers discharge into the Gulf of Ton Kin and the South China Sea, or East Sea. The watersheds of the nine main rivers cover about 70% of the total land area of Vietnam. The characteristics of these main river systems are presented in Table 4.21.

The average precipitation in Vietnam is about 1,900 mm/yr, but shows large spatial variation, ranging between approximately 1,350 mm/yr in some areas of the Mekong Delta and 4,000 - 5,000 mm/yr in certain mountain ranges. About 70 to 80% of the rainfall occurs during the rainy season, which in most of the country, is from May to November. The most significant atmospheric disturbances causing rains are the typhoons, resulting in rainfalls lasting up to four consecutive days, with recorded intensities of over 100 mm/hour. Every year an average number of 6 to 7 typhoons hit the coast of Vietnam, causing storm surges of several meters above normal tidal levels.

With respect to land-use, deforestation is one of the most serious problems in Vietnam, with almost 40% of the country being classified as barren, leaving only 30% covered by forests and 20% by agriculture. Of the total population of about 75 million (1995), some 22% (16.5 million) are reported to live in the coastal zone.

2. Five major watersheds

The national inventory of the watersheds of Vietnam covers the Red River, the Thai Binh River, the Thu Bon River, the Dong Nai River, and the Mekong River (See Figure 4.11). Each of these river basins has distinctly different land-use patterns, as depicted in Table 4.22. The combined information on these five watersheds can be considered as sufficiently representative of the range of situations in Vietnam to draw general conclusions. Also, the five watersheds cover over 60% of the land area of Vietnam and contain about 60% of the total population of the country.

With respect to the use of agricultural land, the main crop is rice, with "other cereals" being second (see Table 4.23). In most watersheds, about 85% of the population lives in rural areas. Only in river basins that contain major cities such as Ho Chi Minh City, Hanoi, and Da Nang does the percentage of rural population become less.

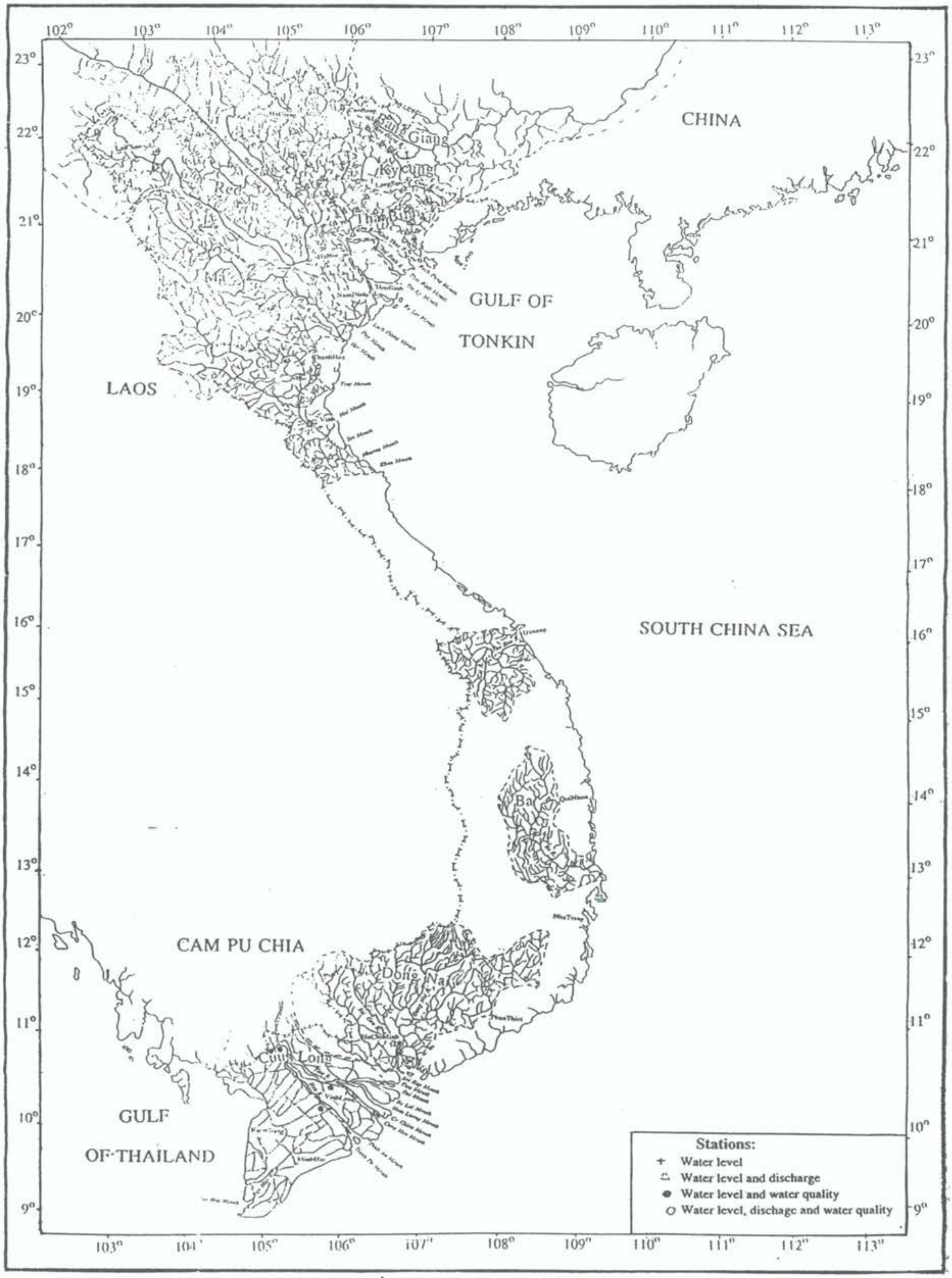
3. Information on waterflow and sources of pollution

For all five river basins included in the inventory, detailed average rainfall statistics for typical stations have been given for annual and monthly precipitation data. For all rivers and their main tributaries, the monthly and annual average water levels, together with their corresponding water discharges, are available. Reference is also made to the existence of major reservoirs, indicating their surface area, and water controlling volume (related to the percentage of annual flow of the river upstream of the reservoir). The largest discharge comes from the Mekong, with 550 billion m^3/yr and a maximum flow in the rainy season of about 40,000 m^3/s, and minimum flow at the end of the dry season of about 2,000 m^3/s.

For many rivers, the average monthly distribution of turbidity is given. Most average monthly values range between 50 and 2,500 mg/l. These figures can subsequently be related to the data on water discharges in order to arrive at average monthly sediment loads. Some data on maximum recorded turbidity levels have also been included (15,000 -20,000 mg/l).

The Red River transports an estimated 115 million tons/yr of sediments, making it eighth in the world with respect to sediment load. The total sediment load carried by all Vietnam rivers together surpasses 200 million tons/yr, with more than 90% of this volume being discharged during the rainy season. The turbidity of the Mekong River is significantly lower than that of the Red River and is between 375 and 500 mg/l during the rainy season and 50 to 100 mg/l during the dry season.

Figure 4.11 Map of main river systems and their catchments in Vietnam.



Source: EAS-35 Second Workshop, 1995

Table 4.21 Characteristics of the main river systems in Vietnam

River system and rivers	Watershed area (km^2)	River length (km)	Average elevation of watershed area (m)	Average slope of watershed area (%)	Annual average discharge (m^3/s)	Total annual water volume (km^3)
I. Red river system						
1-Thao	51,750	902	647	29.9	796	26.4
2-Da	52,610	1,013	965	36.8	1,744	56.4
3-Lo	38,970	469	884	19.7	980	32.2
4-Hong	154,720	1,126			3,630	114.0
II. Thai Binh System						
1-Cau	6,064	288	190	16.0		4.7
2-Thuong	3,580	164	186	9.4	43.7	1.76
3-Luc Nam	3,066	175	207	16.5	32.8	1.8
4-Thai Binh	15,520	385			38.6	9.0
					318	
III. Kycung-BanGiang system						
1-Kycung	6,663	243	386	18.1	26.9	0.85
2-Bang Giang	4,565	108	482	20.1	73.5	2.4
IV. Ma system						
1-Ma	28,370	538	762	17.6	326	10.8
2-Chu	7,552	325	790	18.3	135	4.9
V. Ca system						
1-Ca	27,224	531	294	18.3	430	13.6
2-Hieu	5,330	228	303	13.0	112	3.82
3-Ngan Sau	3,813	135	362	28.2	124	4.0
4-Gianh	4,676	158	360	19.2	60.8	2.0
5-Quang Tri	2,500	156	301	20.1	104.6	3.3
VI. Thu Bon system	10,590	205	552	25.5	444	14.0
1-Tra Khuc	3,180	135	558	18.5	162	5.1
2-Ve	1,260	91	170	19.9	44	1.4
VII. Ba system	13,814	388	400	10.9	184	5.8
VIII. Dong Nai-Saigon system						
1-Dong Nai	29,520	586	470	4.6	693	29.7
2-La Nga	4,000	272	468	5.6	83	5.3
3-Be	8,200	344	240	5.3	240	10.3
4-Saigon	5,560	256			167	5.2
IX. Mekong system						
1-Se San	17,500					12.5
2-Sre Pock	18,280					10.6
3-Cuu Long	795,000	4,200			13,974	550

Source: Sinh, 1995

Table 4.22 Land-use in Vietnam as a percentage of main watersheds

Land-use	Red River	Thai Binh River	Thu Bon River	Dong Nai River	Mekong River
Forest	21	18	38	47	10
Agriculture	15	32	9	30	75
Aquaculture	0.5	1.5	-	1.5	4
Urban	0.5	0.5	1.5	1	}
					}11
Other	10	17	12.5	}	}
				}20	
Barren	53	31	39	}	
Total	**100**	**100**	**100**	**100**	**100**

Source: Sinh, 1995

Table 4.23 Main agricultural crops in km^2 by watershed

River	Autumn rice	Winter rice	Spring rice	Other cereals	Agricultural land (total)
Red	-	6,107	4,258	4,145	10,798
Thai Binh	-	3,415	2,681	1,353	5,227
Thu Bon	200	480	378	259	902
Dong Nai	1,587	2,935	2,027	908	11,393
Mekong	10,074	8,154	7,108	388	29,247

Source: Sinh, 1995

The inventory gives detailed information on the amounts and types of chemical fertilizers used in the agricultural areas within each of the river basins. The inventory also mentions that it is estimated that only 30 to 40% of the fertilizers are absorbed by the plants, especially with respect to nitrogen and that 60 to 70% of it is apparently lost. At quite a number of water quality observation stations, the phosphate and nitrate concentrations were recorded under dry season and rainy season conditions. No efforts have (yet) been made to correlate the possible sources of nutrients with estimated nutrient discharges during the dry and rainy seasons. Nutrient levels in the coastal waters are reported to be close to critical values in Danang, at the Minh Hai coast, and in Ho Chi Minh City. At a number of sites in the Mekong Delta, eutrophication has been observed.

At a number of water quality monitoring stations, data have been collected on Hg, Cu, Pb, Cd, Zn, Co, Ni, As, DDT, and Phenol during the rainy season and the dry season, which give a first indication of the levels of these substances. Further studies will be required to link these data to possible sources - most likely industrial activities. The use of agrochemicals is steadily increasing. In 1991, over 20,000 tons of pesticides were used, among them DDT and lindane. DTT and lindane concentrations in coastal waters exceeding 10 times the acceptable levels have been encountered in some estuarine regions of Vietnam. For the agricultural areas within each of the watersheds, data are available on the total amounts of pesticides used.

Most of the organic pollution due to industrial activities, human settlements, and agricultural activities (especially livestock breeding) is discharged into the rivers without treatment. The inventory makes a first attempt to calculate the magnitude of organic pollutant loads on the basis of the WHO guidelines for rapid assessment. A special feature is the large number of pigs, hens, and ducks that are reported, which greatly outnumber the inhabitants - especially in the coastal areas. This intensive livestock breeding will also have an effect on the nutrient loads discharged into the rivers.

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SECTION 5. LINKAGES BETWEEN ACTIVITIES IN THE WATERSHEDS AND STATUS OF THE COASTAL AND MARINE ENVIRONMENT

5.1 INTRODUCTION

Land-based activities in the EAS region are widely believed to cause degradation of the coastal and marine environment (Chou, 1994, and Yap and Gomez, 1985). However, few studies from the region actually portray direct impacts on coastal and marine ecosystems by land-based sources of sedimentation, nutrient-loading, and pollution (SNP). EAS-35 Project provides an opportunity to explore the relationship between land-based activities and the degradation of coral reefs, seagrass beds, and coastal wetlands.

Under the EAS-35 Project, the ten COBSEA member-countries each synthesized available knowledge and information from various study areas into an inventory. The study sites were defined as a river and its watershed which drains into representative coastal and marine ecosystems preferably comprised of coastal wetlands, seagrass beds, and coral reefs.

Although this project builds on previous EAS projects, particularly with respect to the impact of pollutants, EAS-35 has a different intent. It attempts to assess the nature of pollutants and their impacts on coastal and marine ecosystems, albeit in small geographic areas. EAS-35 is also wider in scope, including the assessment of sources and impacts of sediments and nutrients on coastal wetlands, seagrass beds, and coral reefs.

The previous chapters have synthesized the status of coral reefs, seagrass beds, coastal wetlands, and watersheds of the chosen ecological sites in the ten participating countries. In this chapter, the linkages between land-based activities and coastal and marine degradation are highlighted with regard to possible causes and perceived impacts of SNP.

5.1.1 Materials

This chapter is based on the national inventories and synopses prepared by the ten participating countries. Both the national inventories and synopses were prepared from existing data, reports, and publications with the exception of Thailand where the synopsis was a field study of the Praesae River Basin and its associated marine environments. These national inventories have been summarized under the thematic topics of coral reefs, coastal wetlands, seagrass beds, and watersheds in sections of the previous chapters. The sites for synopses were located in Malaysia, Thailand, and Vietnam.

Table 5.1 shows the sites of watersheds, coastal wetlands, seagrass beds, and coral reefs. Only the countries that have chosen ecological sites that allow the ability to link activities in watersheds with their impacts on coastal and marine environments are included in the table.

Table 5.1 **Selected sites for the national inventories from the EAS-35 Project: each represents an integrated land, coastal, and marine ecological site.**

Country	Watershed	Coastal Wetlands	Seagrass Beds	Coral Reefs
Australia	Herbert River Catchment	Hinchinbrook Island	Hinchinbrook Channel	Townsville, Port Douglas
Cambodia	7 watersheds, including Prek Kapong Prek Toeuk Sap, Stung Metoek	Prek Kapong (Kampot) Prek Toeunk Sap	Kampot Kampot Som Kok Kong Kampong Som Bay	Koh Kong Kampot Sihanouk-ville
China	Pearl River System	Pearl River Delta	Shen Zhen	Hainan Island
Indonesia	Cisadane-Ciliwung River basin; 13 rivers	Muara Angke M. Gembong Tanjang Karawang, T. Sedari, Citarum delta, NE Jakarta	Jakarta Bay	Seribu Islands, Jakarta Bay
Korea	Kum River Yongsam River	Kum River Yongsam River		
Philippines	Lingayen Gulf	Lingayen Gulf	Lingayen Gulf	Lingayen Gulf
Singapore		Sungei Buloh, Mandai, and several Pulaus	Southern Islands, Labrador Beach, Changi Beach	all reefs
Thailand	Tapi-Phun Duang (drains to Ban Don Bay)	Phangnga Bay (west coast of Thailand)	Phangnga Bay	Ban Don
Vietnam	Red River watershed; Thai Binh R, Thu Bon, Dong Nai, Mekong	Tam Giang-Cau Hai Lagoon; Red River	Cat Ba Islands, Halong Bay, Tam Giang-Cau Hai Lagoon	Halong, Bai Tulong, Cat Ba

Source: EAS-35 National Inventories, 1995

5.2 IMPACTS OF SEDIMENTATION, NUTRIENT LOADING, AND POLLUTION (SNP)

5.2.1 National inventories

The sources of SNP are not only limited to the upper watershed. Activities in coastal wetlands (Table 5.2) in most countries also contribute to SNP in the marine environment.

It is apparent from Table 5.2 that anthropogenic causes of SNP in the downstream ecosystem are widespread in the EAS region. In general, the impacts of land-based SNP are observed or perceived, but documentation and quantification of impacts on downstream ecosystems are still limited.

The Australian inventory indicates that the sources of SNP from human activities affect the water quality in nearshore waters. As a result, the growth of many seagrasses is negatively impacted. It is also assumed that the unusually tall growth exhibited by *Halophila tricostata* is due to high sedimentation levels.

In the Philippines inventory, it is shown that the deposition of mine tailings in the Agno River Basin may be the primary cause of sedimentation in the Lingayen Gulf. In the coastal wetlands, the impact of this sedimentation can be seen as the cause of increased mortality of mangrove saplings as was observed in other mangrove areas in Batangas Bay. This sedimentation is considered to have the potential to smother and kill areas of seagrass beds. Some corals found near the mouth of the Agno River seem to have adapted to the silty environment, however, branching corals are absent.

5.2.2 Synopses

Examples of linkages between activities in watersheds and impacts on related coastal and marine sites were reported from Indonesia, Malaysia, the Philippines, Thailand, and Vietnam (see Table 5.2).

In the Cisadane-Ciliwung River and Jakarta Bay study area (see Table 5.2) degradation of forests and mangrove stands has resulted in high sedimentation of Jakarta Bay to the extent that:

i. fewer coral species exist inshore than offshore;
ii. coral growth rates are reduced;
iii. the maximum depth of coral colonization was reduced due to high turbidity.
iv. total coral cover was reduced;
v. live coral cover was reduced; and
vi. the community structure was changed from that dominated by autotrophic to heterotrophic species.

In Malaysia, the diversified development of Pulau Langkawi has caused increased sedimentation. This has resulted in the reduction of live coral cover from 46% to 30% in a span of just 6 years.

In the Prasae River Basin, in Thailand, the environmental threat to downstream ecosystems stems from an increasing sedimentation rate as a result of deforestation and poor methods of cultivation. Coral reefs were found to have live coral cover ranging from 10-60%, but more significantly, the ratio of live coral to dead coral was only 4.05%.

Coral bleaching was also observed, but it is unclear whether this was caused by the high sedimentation rate or nutrient-loading from the river basin. It was also noted that possible sources of nutrient-loading were found in coastal areas.

In the Red River Delta of Vietnam, the watershed activities of coal mining, deforestation, and agricultural practices were found to contribute to the degradation of marine ecosystems. Siltation resulted in the reduction of seagrass beds and coral reefs. Water clarity improved with the distance from shore.

5.3 DISCUSSION

5.3.1 Sources of Sedimentation, Nutrient Loading, and Pollution (SNP)

Activities leading to SNP were reported in the watershed and also in coastal wetlands (Table 5.2). The implication of this, is the need to develop integrated management measures to address the causes and impacts of SNP in watersheds, coastal wetlands, and marine ecosystems. In order to develop appropriate management plans and mitigation measures, it is necessary to identify terrestrial locations and activities within the watersheds that lead to SNP and the resulting impacts on the marine environment.

5.3.2 Linkages

Sediments, nutrient-loading, and pollutants are known to result from activities in watersheds and coastal wetlands of all countries, but documentation and quantification of impacts are very limited in the EAS region. Isolated studies within the region, however, provide evidence of detrimental impacts (Aliño, 1984; Maaliw et al. 1989). Environmental problems attributed to land-based SNP in the marine environment are prevalent to the extent that various methods have been designed to measure, monitor, and detect SNP impacts over the last 10 years (e.g., Chou, 1994).

The linkages indicated between watersheds and the coastal and marine environments based on the "national inventories" are generally qualitative in nature. Significant gaps in knowledge exist and due to the limited time-frame and resources within the EAS-35 project, studies to identify and quantify SNP sources and relate them to the conditions of the coastal and marine environments could not be conducted.

Qualitative linkages have been observed between activities in watersheds and/or coastal wetlands with the states of the seagrass beds and coral reefs. These findings are constrained by the number of ecological sites included in the EAS-35 project but should be viewed as critical indicators. The limited number of ecological sites that were examined under the project were not sufficient to show all the detrimental impacts of SNP. It is possible that other site-specific characteristics upstream or downstream could affect the magnitude of the impacts of SNP. For example, the movement of sediments is also affected by the topography of coasts (e.g., embayment principle; Gomez et al, 1995).

Natural forces can also add to the degradation of coastal and marine ecosystems. For example, natural erosion processes increase sedimentation associated with agricultural activities within the drainage system, especially when these agricultural practices are conducted using poor land management techniques. Also, seagrass beds and coral reefs can be affected by storms and lowered salinity as a result of natural flooding. However, human activities significantly increase the environmental degradation caused by natural processes.

Table 5.2 Impacts of activities in the watershed and coastal wetlands on seagrass beds and coral reefs.

Country	Watersheds	Coastal Wetlands	Seagrass Beds	Coral Reefs
Australia	S - forestry, urbanization, agriculture N - domestic waste, agriculture P - agriculture	S - mangrove clearing for aquaculture	growth limited to depth of 3.5 m; *Halophila tricostata* is unusually tall, 6-8 nodes above sediment	no apparent impact from anthropogenic activities; increase in nutrients associated with sediments occur with occasional flooding; the decrease in salinity cause coral bleaching and death of corals up to 9m
Cambodia	S - logging of forests N - agriculture and domestic waste P	S - mangrove clearing	affected (but no details)	water is turbid and may affect coral reefs
China	S - soil erosion N - domestic and industrial wastewater, agriculture P - industrial water containing heavy metals	S - mangrove clearing	no info	acknowledges that reefs are threatened by SNP (but no available data)

Country	Watersheds	Coastal Wetlands	Seagrass Beds	Coral Reefs
Indonesia	S - deforestation N - agriculture P - industrial	S - mangrove clearing	no info	water quality deteriorated between 1929-1993; water clarity is correlated with distance from land ($r^2 = 0.76$) effects: i. reduction in coral cover ($r^2 = 0.58$) ii. degradation of coral reefs in 28 islands in terms of coral cover; i.e., from 30% (1985) to < 5% (1995) iii. maximum depth of coral distribution decreased from 9 m (mean in 1929) to 4 m (1993) iv. decline of coral species richness (96 spp in 1929 to 16 spp in 1993) v. number of coral species increases with distance from land ($r^2 = 0.82$) vi. absence of fish species Napoleon wrasse
Korea[1]	S - erosion N - P - agricultural, toxic metals, organic pollutants	S - erosion N - P - impact of threats on wetlands: destruction of integrity of coastal wetlands	not applicable	not applicable

[1]The Republic of Korea is located beyond the northernmost distribution of seagrasses and coral reefs.

Country	Watersheds	Coastal Wetlands	Seagrass Beds	Coral Reefs
Malaysia	S - sedimentation from logging, agriculture, tourist development, clearing for industrial/urban estates N - P - N - P -	S - reclamation; coastal erosion N - P - pollution		mortality of corals in highly turbid areas
Philippines	S - mining industry and logging N - untreated sewage and poor agricultural practices P - mining: heavy metals	S - mangrove clearing; fuel gathering; illegal logging; slash-and-burn agriculture impact of cement discharge: limits natural regeneration of mangroves	smothering of seagrass beds	smothering of coral reefs
Singapore	S - dredging and reclamation N - (minimal) P - horticulture and animal husbandry	S - dredging	loss of seagrass beds	reduction of water visibility (10 to 2 m) has not affected coral reefs
Thailand	S - soil erosion and mine tailings N - agricultural, PO_4 + NO_3 P - domestic	S - mangrove clearing for aquaculture N - N, P in addition: antibiotics are discharged to the sea		decline in water quality

Country	Watersheds	Coastal Wetlands	Seagrass Beds	Coral Reefs
Vietnam	S - sedimentation mainly from coal mine and partly from deforestation (Red River Delta) N - agricultural and animal husbandry P - (organic), domestic, industrial	S - clearing for aquaculture	possible decrease in area	smothering and then death of corals possible effect of eutrophication

Source: EAS-35 National Inventories, 1995

5.4 CONCLUSION

Sedimentation, nutrient-loading, and pollution generated by land-based activities in watersheds adversely affect coastal and marine ecosystems. It is also recognized that development activities in coastal wetlands adversely affect nearshore marine ecosystems. Despite the fact that these findings are limited by a paucity of research resources and present gaps in knowledge, they are significant in that they represent a first attempt in the EAS region to study the origins and impacts of SNP within one comprehensive system that integrates watersheds, coastal wetlands, seagrass beds, and coral reefs. The EAS-35 project has provided an assessment of the impacts of heightened SNP loads arising from activities in watersheds and coastal wetlands on seagrass beds and coral reefs. Thus, it provides a basis for developing integrated management plans to address land-based activities that contribute to SNP and to protect downstream coastal and marine ecosystems.

Furthermore, the limited, qualitative nature of the findings from the EAS-35 project should not prevent resource managers or policy makers from adopting the precautionary principle or undertaking mitigation measures to deal with land-based sources of SNP (as embodied in the Montreal Protocol and subsequent agreements, especially the Global Programme of Action for the Protection of the Marine Environment from Land-based Activities, October, Washington, 1995). The application of the precautionary principle along with research on the assimilative and cumulative capacities of ecosystems (Noreena and Wells, 1989) accompanied by monitoring of impacts are imperative for integrated management of land-based sources of SNP.

5.5 SYNOPSES

The following synopses from Malaysia, Thailand, and Vietnam present some linkages between land-based sources of SNP in the watershed and related impacts to the costal zone, seagrass beds, and coral reefs. The information presented in each synopsis varies due the different levels of detail and formats that were presented in the national reports from each country.

5.5.1 Malaysia

Site selected: Pulau Langkawi, Northwestern coast of Malaysia

<u>Watershed and Drainage Basin</u>:

Uses:

i. settlement areas
ii. agriculture

Threats:

i. domestic pollution
ii. erosion

Wetlands:

Uses:

i. fishery sites
ii. wood production
iii. shore protection

Threats:

i. land reclamation
ii. conversion to aquaculture
iii. land-filling

Seagrass Beds:

Uses:

i. no uses specified

Threats:

i. diversified development: agriculture, housing, industry, waste-water treatment disposal
ii. land reclamation

Coral reefs:

Uses:

i. reef fauna habitat, food production
ii. tourism

Threats:

i. sedimentation from clearing vegetation
ii. backyard industrial activities
iii. low salinity from excessive run-off

Impact:

i. corals in shallow waters have died either from exposure to air during low tides or smothering by sediments
ii. reef deteriorated from 46% (1988) to 30% coral cover when visibility was reduced to 1.5 m in 1995

5.5.2 Thailand

Site Selected: Prasae River Basin, eastern coast of the Gulf of Thailand

General Description: The watershed of Prasae River is 2,000 km^2 and the drainage basin is located in Chon Buri and Rayong Provinces. Prasae River drains into the Gulf of Thailand.

Ecological Importance:

i. natural resources conservation area
ii. fishery area

Uses:

i. settlement sites
ii. agriculture
iii. industrial zone
vi. fishing area

Watershed and Drainage Basin:

Water quality standards in the river and coastal area are within Thailand's Inland Surface Water Quality Standards and Coastal Water Quality Standards. However, agricultural pollutants, such as nitrogen, phosphorus, and pesticides are discharged into the river. Suspended solids generally decrease from the upper watershed and coastal areas to the marine environment.

Biological oxygen demand tends to be higher in seagrass beds than coral reefs while NH_3-N was high in wetlands and seagrass beds. Nitrite, nitrate, phosphate, and total phosphorus decrease with distance from the shoreline. Suspended solids and total coliform tend to decrease from as one moves further out to sea.

Sediment Transport:

Total sediment transport is 61 tons/km^2/year and increasing with deforestation and poor methods of cultivation.

Sources of Biological Oxygen Demand:

i. industrial
ii. domestic
iii. aquaculture

Wetlands:

The coastal wetlands were mainly mangrove forests which have decreased significantly through the years (from 34400 rai in 1975 to 970 rai in 1992; one rai equals 1600 m^2).

Seagrass Beds:

Seagrass beds are found between 1.0-1.3 m deep up to a distance of 400 m offshore. The percent cover is between 13%-15%. Fish and other marine organisms are found in the seagrass beds.

Coral reefs:

Please see Table 5.3.

Table 5.3 Coral reef characteristics on sites presented in Thailand synopsis

Parameter	Mun Nai reef	Mun Klang reef	Mun Nok reef
% live coral cover	reef flat and slope - 10%; reef flat on western part of island - 60%	eastern part: 15-20% northern part: 55. 29%	eastern part: 57.12% northwestern: similar cover as eastern part; moderate condition
% dead coral cover	62.10%	eastern part: 50-60% northern part: 42.53%	26.70%
dominant species	*Porites lutea* *Pavona* sp.	*P. lutea* and *Pavona* sp.	eastern part: *Porites*, *Acropora*, and *Turbinaria* northwestern part: *P. lutea*, *Acropora*
sand			15.78%
threats	none identified	none identified	none identified
impacts			coral bleaching but cause unknown

Source: Sanpanich, 1995

5.5.3 Vietnam

Site Selected:

Red River System in northern Vietnam

General Description:

The Red River System is one of the biggest river systems in Vietnam. Its drainage area covers 7 provinces (16,644 km^2). The riverine waters drain into Hai Phong Bay in the Gulf of Tonkin.

Watershed and Drainage Basin:

For this synopsis, the watershed of the Red River Delta has 16% (256,900 ha) forest land and of which 5% (81,00 ha) has forest cover. The remaining area is bare land.

The forest is further subdivided into production forests (40,000 ha), protection forest (38,000 ha), and special forests (41,200 ha).

The average rainfall is 1,740 mm/yr.

Uses of Delta:

i. settlement - 20% of Red River Delta
ii. agricultural - 54%
iii. aquacultural

Threats to the Delta:

i. typhoons - 15 per 10 years (natural)
ii. salt-water intrusion (natural)
iii. deforestation of mangrove forests in Quay/Ninh Coast

Impact of Deforestation in Watershed:

i. change of hydrological patterns; increased flooding

Uses of River and Tributaries:

i. transport
ii. seaport
iii. source of irrigation and potable water
iv. industry, producing 17% of GNP

Major Industries:

a. textile and footwear
b. cement and construction materials
c. chemical and fertilizer industries
d. metallurgy
e. mechanical/electrical engineering industries
f. electronic industries and information technology
g. food processing
h. handicraft

Sources of sedimentation, nutrient-loading and pollution:

1. Sedimentation - erosion as a result of deforestation contributes 140-150 m tons/yr from (see Regional Overview on watersheds for more details)

2.a. Nutrient-loading (in millions of metric tonnes per year)

organic matter	:	1.8-2.0 m tonnes/yr
N_2	:	0.2-0.25 m tonnes/yr
K_2O	:	0.27-0.90 m tonnes/yr
P_2O	:	0.14-0.30 m tonnes/yr

2.b. agricultural, domestic, and industrial wastewater (million meters^3 per year)

total discharge (Hanoi) - 110 m^3 /yr
total discharge for Red River Delta - 330 m m^3/yr

3. pollution/contaminants - low levels

Wetlands:

Area of Coastal Wetlands - 100,000 ha of various types

Uses:

i. settlement
ii. agriculture
iii. aquaculture

Threats:

i. construction of dykes and aquaculture production facilities
ii. cutting for wood
iii. pollution from agriculture; pesticide use is intensive at 10 kg of active ingredient/ha
iv. Industrial centers for shipyards, chemical production, seafood processing, paper production, cement production, and steel production include: Viet Tri, Hanoi, Hai Phong, and Quang Ninh.
v. mines near the coast near Quang Ninh produce 3 million tons of coal and discharge coal dust with the grain size of 50 micrometer into the air and courser sediment into the sea.

Impact on tidal wetlands:

i. sedimentation in Cua Luc embayment
ii. deposition of heavy metals (Cu, Pb, Cd, Hg) in water and sediment is higher than permissible standards (standards not listed).
iii. residues of Lindane, DDE, and DDT are higher in sediments and benthic organisms than in water.

Seagrass Beds:

Threats:

i. heavy metal pollution
ii. turbidity as a result of wave action and monsoonal winds on sediment deposits
iii. turbidity from deforestation of mangroves, dredging of channels, and coastal navigation
iv. oil pollution in Hai Phong (0.2 -3.4 mg/l and exceeding the allowable limit for aquaculture)

Impact of sedimentation:

i. the distribution of *Halophila beccari* and *Ruppia maritima* has decreased by 50%.

Impact of nutrient-loading:

i. fertilizer used in aquaculture production of *Gracilaria asiatica* in brackish water ponds has produced algal blooms which reduce light penetration for photosynthetic activity of seagrass beds ultimately reducing the areal cover

Coral Reefs: (in Ha Long, Bai Tu Long, Cat Ba area between Quang Ninh and Hai Phong Province)

Threats:

i. high turbidity and suspended solids (50-90 mg/l or 1.4-10 mg/cm^2/day); sedimentation is higher on the reef flat than reef slope
ii. pollution from oil, heavy metals

Impacts of turbidity:

i. reduction of species nearshore (no numbers provided)

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