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Core Project of the
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with

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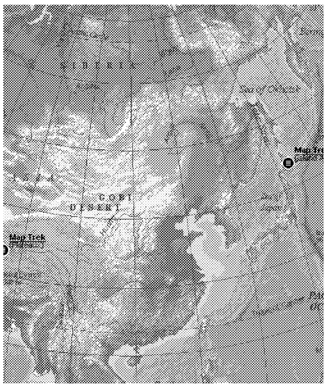

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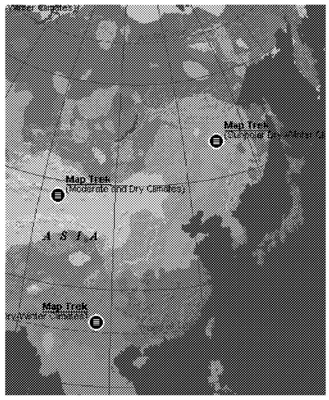

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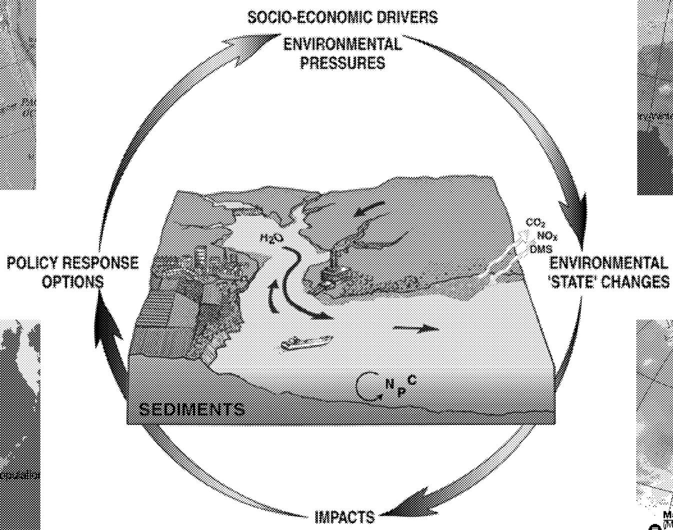

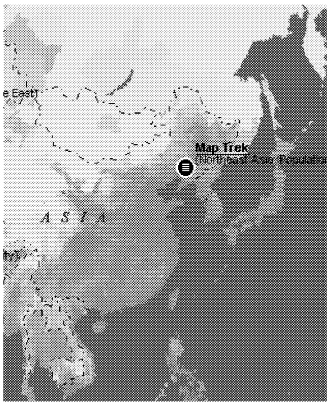

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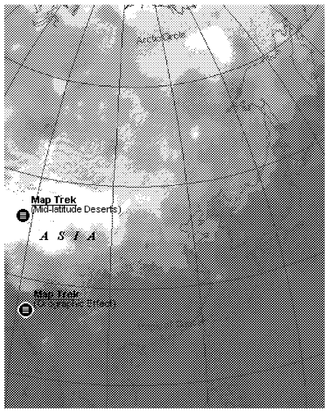

Precipitation

East Asia Basins

香港浸會大學
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LOICZ Global Change Assessment and Synthesis of River Catchment–Coastal Sea Interaction and Human Dimensions

Compiled and edited by G.H. Hong, H.H. Kremer, J. Pacyna, Chen-Tung Arthur Chen, H. Behrendt, W. Salomons and J.I. Marshall Crossland

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LOICZ REPORTS & STUDIES No. 26

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by

G.H. Hong, H.H. Kremer**, J. Pacyna***, Chen-Tung Arthur Chen****, H. Behrendt*****, W. Salomons****** and J.I. Marshall Crossland***

** Dept. of Marine Biogeochemistry and Isotopes, Korea Ocean Research & Development Institute, Seoul, Republic of Korea*
*** LOICZ International Project Office, Texel, The Netherlands*
**** Norwegian Institute for Air Research (NILU), Kjeller, Norway*
***** Institute of Marine Geology and Chemistry, National Sun Yat-sen University, Taiwan*
****** Institute of Freshwater Ecology & Inland Fisheries, Berlin, Germany*
******* Free University, Amsterdam, The Netherlands*

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1. EXECUTIVE SUMMARY

by G.H. Hong, H.H. Kremer and Wim Salomons

The LOICZ Core Project

Coastal zones world-wide are subject to many pressures which are expected to continue or increase. The nature of these pressures changes with time. In Europe and North America, the impact of "classical" contaminants such as heavy metals, nutrients and PCB's has drastically decreased whereas nutrient inputs have stayed high over recent decades. In emerging economies, nutrients have a higher priority. New classes of chemicals have entered the priority lists of international organisations and these will require impact monitoring studies. Increasingly the coastal zone itself is subject to competition for space. This includes pressures such as urban and industrial development, tourism and increased traffic, which all demand physical space and hence cause a decrease in the size and functioning of the coastal ecosystem. In addition, past and planned physical changes in river catchment (e.g., damming, diversion) influence the natural flow of water, nutrients, sediments and pollutants to the coast. Numerous studies (often mono-disciplinary) dealing directly with these issues have produced large amounts of data but only rarely have they been reviewed from an integrated assessment and synthesising angle. Even more rarely has the interaction between the biogeochemical environment and the human historical development of a given site been considered in proper context.

LOICZ, the **Land Ocean Interactions in the Coastal Zone** core project of the International Geosphere Biosphere Project (IGBP), is paying increasing attention to people issues in coastal change. Coastal zones are seen as an integral part of the water cascade, including river catchments and their response to external forcing from both anthropogenic and natural changes. The LOICZ key questions addressing the coastal issues are:

- How are humans altering the mass balances of water, sediment, nutrient and contaminant fluxes, and what are the consequences?
- How do changes in land use, climate and sea level alter fluxes and retention of water and particulate matter in coastal zones, and affect morphodynamics?
- How can we apply knowledge of processes and impacts of biogeochemical and socio-economic changes to improve integrated coastal management?

Within LOICZ, the LOICZ-Basins core project is working *inter alia* to develop a global assessment of the importance of change in coastal seas by applying a systems approach. The river catchment (or island) and its associated coastal zone are treated as one system (Figure 1.1). In this system the change in the coastal zone is the result of local human activities, whose actual impact depends additionally on its biophysical properties. On a global scale, coastal zones will show different responses to a similar human activity. The regional system is subject to outside (long-term) pressures and drivers which include climate change and the global socio-economic trends and changes. To elucidate these intricate internal and external relationships, LOICZ Basins focuses on the horizontal flux of substances within the catchment (island) coastal zone system. The systems approach requires an integration of the natural and social sciences to address such issues as critical concentrations and loads, resilience and carrying capacity. The DPSIR framework developed by the OECD has been adapted by LOICZ for this integration.

To generate a global picture, LOICZ-Basins co-ordinates a series of standardised, thus comparable, regional workshops to scale up the information from single river catchment/coastal sea interacting systems to bigger sub-regional and regional scales. In doing this, characteristic types or classes of coastal issues and changes are identified, prioritised and linked to their major natural and anthropogenic drivers on a river catchment or island scale. Numeric or qualitative indices are developed to allow this prioritisation and to compare the scenarios of land-driven coastal change in a qualitative or semi-quantitative way within and across regions. This aims to enable the visualisation/ mapping and up-scaling of the issues and scenario simulation on various spatial and temporal scales. It is expected also to ultimately feed into the typology effort for global up-scaling, which is under continued development in co-operation with IGBP/BAHC – the Biosphere Aspects of the Hydrological Cycle core project.

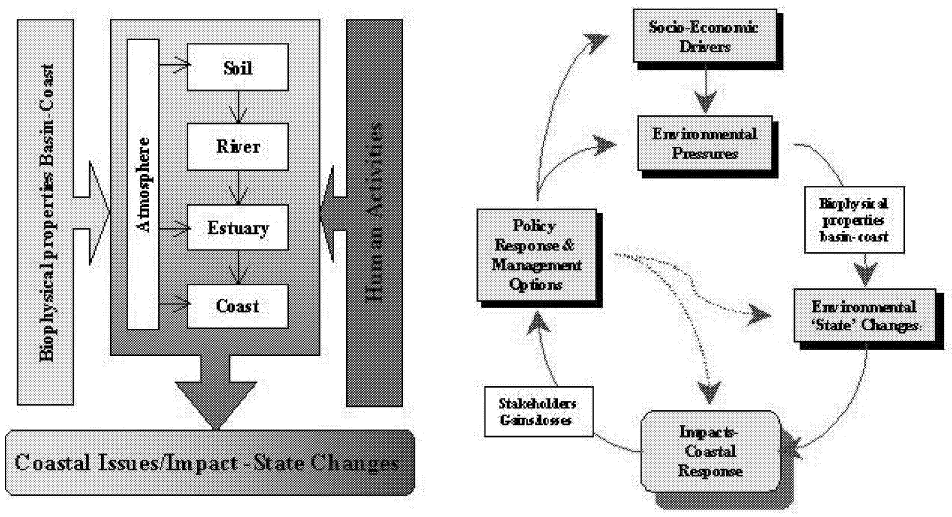


Figure 1.1. The catchment-coastal zone system and the DPSIR Framework.

The East Asia Basins workshops

The LOICZ East Asia Basins assessment and synthesis workshop was held at the Baptist University in Hong Kong in February 2001, to obtain an overview of the current understanding of catchment-coastal sea interaction in East Asia. The region considered in the East Asian Basins Workshop stretches from the South China Sea north to the Bering Sea. Countries involved are Vietnam, China including Hong Kong SAR, Korea, Russian Federation, Japan and Taiwan.

East Asia encompasses a wide range of climatic conditions from tropical areas to arctic tundra along the south–north axis. A general pattern can be found in the decrease of annual precipitation from the humid coast to desert-like region in the inland. However, for the assessment and synthesis process three sub-regions were identified: the tropical, temperate and cold temperate climate regimes of southern, central and northern East Asia. Divided by sub-regions, three working groups provided a set of qualitative typological classes of drivers and change and a first-cut qualitative ranking and trend analysis. Those will be applicable for regional and global comparison of DPSIR scenarios. A first approximation of distances of coastal state changes to related thresholds for system functioning was also developed. Information needs, data gaps and a list of "hot spots" - sites with negative expectations - were compiled.

Overview of the East Asian coastal zone-catchment system

The East Asian region comprises the eastern and southern side of the Euro-Asian continent, and is dominated by a number of very large river catchments and wetlands east and south of the Himalayas as well as eastward-flowing rivers traversing grasslands in the cold temperate Far East of the Russian Federation. The huge streams interact with wide areas of the coastal zone in the southern and central region, but considerable parts of the coastline are also influenced by relatively small and medium catchments. Riverine freshwater and nutrient supply determines the major part of the primary production and fisheries of the East Asian marginal seas: the South China Sea, East China Sea, Yellow Sea, Bohai, Sea of Japan with greater impacts, and the Sea of Okhotsk and Bering Sea with lesser impacts. Most rivers have been drastically altered through human activities and their pressures on the coastal zone are more pronounced than in other areas in the world. China alone supports more than 1 billion people, accounting for one-sixth of the total world population. Consequently, land use and cover change, pollution or water diversion, which are examples for drivers and pressures changing horizontal mass transport, are likely to cause stronger coastal state changes and to generate "hot spots" of impact through out the marginal seas of East Asia. The islands of Japan and Taiwan are also heavily populated, so human interference in the river catchments and flow regimes is very intensive.

The LOICZ East Asia Basins workshop identified and compiled coastal change and catchment-based drivers by considering the following features:

- Coastal geomorphology
- Coastal habitats/biodiversity
- People relationships (demography and drivers)
- Catchment size and seasonal run off features
- Land use and cover characteristics
- Climate influence

Along the coast of the South China Sea, the following areas were delineated (Figure 1.2):

➢ Area 1 corresponds to the high rainfall coast of Vietnam and southern China, including important rivers with large sediment yields such as the Mekong and Red River in Vietnam and Pearl River in China.

➢ Area 2 corresponds to the East Asian Monsoon region, along the coast of the East China Sea, Yellow Sea and Bohai Sea. This is characterised by wet summers and dry winters, and encompasses important rivers with large sediment yields such as the Yantgtze and Yellow rivers and smaller systems such as the Hai and Liao rivers. The Korean Peninsula, Japan and Taiwan are also included.

➢ Area 3 corresponds to the cold temperate and arctic coast along the coast of the Sea of Japan (East Sea), Sea of Okhotsk, and Bering Sea, including important rivers with large sediment yields such as the Amur system and smaller rivers such as the Anadi(y)r and Tumen rivers.

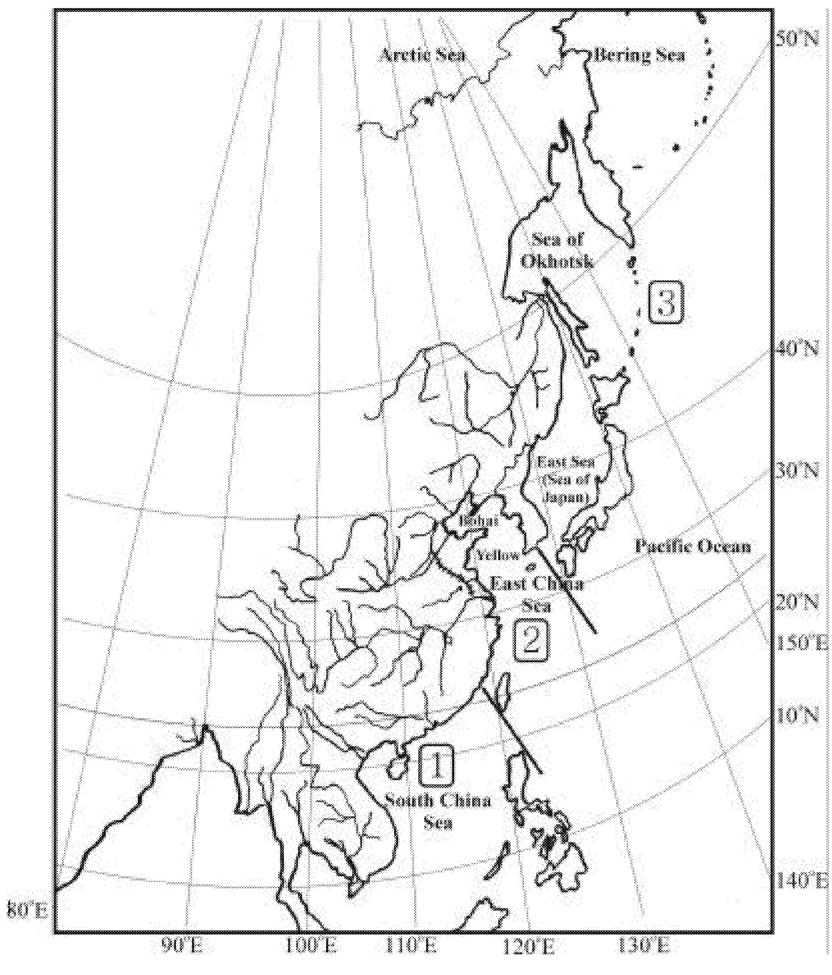


Figure 1.2. Sub-regional division for the assessment of river catchment–coastal sea interaction classes, based on expert judgement and mainly climate-driven.

The key anthropogenic pressures identified vary. A ranked list was drawn up for the region, together with expected future trends in impact (Table 1.1).

Table 1.1. Major activities and present status and trends affecting the coastal zones in East Asia

Activity	Major Impact	Present status	Trend expectations	Major areas affected (as for Figure 1.2)
Urbanisation	Eutrophication and water extraction	Major	Increasing	1,2
Agriculture	Eutrophication, pesticide pollution, reclamation, over-grazing	Major	Increasing	1,2,3
Damming/diversion	Freshwater, nutrient, and sediment sequestration/ coastal erosion	Major	Increasing	1,2,
Deforestation	Habitat loss/modification Erosion/sedimentation Saltwater intrusion	Major	Decreasing	1,2,
Aquaculture	Eutrophication	Major	Increasing	1,2
Industrialisation	Pollution/Harmful Algal Blooms (HABs)	Medium (Major at local scales)	Increasing	1,2,3
Mining (terrestrial and offshore)	Loss of habitat and biodiversity	Medium	Increasing	1,3
Land reclamation	Sediment budget alteration	Low	Increasing	1,2

The list in Table 1.1 characterises a developing economy and high population pressure situation. Economic growth is frequently not followed at the same pace by the necessary urban and industrial infrastructure. As a result the major impacts on the coastal zone caused by catchment-based activities are eutrophication and pollution, linked to urbanisation and the rapidly increasing demand of water and energy by the fast-growing economies. Increased efforts in damming and diversion of river courses resulting in erosion/sedimentation problems at the coast. Agriculture and deforestation affect some areas, in particular those in southern East Asia where tropical typhoons bring torrential rain in a relatively short time causing pulsing freshwater fluxes to the coast. All the activities listed in Table 1.1 also result in a variable degree of biodiversity loss and changes in trophic states and food webs at the coast.

The regional catchment-coastal sea systems

In the workshop, the standardized set of LOICZ-Basins Regional Assessment tables was used and the following issues/key questions addressed:

1. Assessing **Issues/Impacts (critical thresholds)** based on coastal change in the region.
- What are the major impacts (coastal issues) on/in the coastal zone and do we know anything on how close they are to a critical threshold of system functioning?
2. Assessing and ranking of major **Drivers/Pressures** settings generating the **coastal Impact/Issues**:
- Assessing the major (up to 10) driver/pressure settings on catchment level causing coastal change;
- Can we identify spatial scales on which certain driver/pressure settings dominate coastal issues?

3. Assessing and synthesizing **regional Driver/Pressure** settings generating the coastal **Impact/Issues** and expected **trends** in a hierarchical up-scaling approach (local, sub-regional, full regional scales):
- What are the major **driver/pressure** settings causing coastal impact observed and what are the future trends: at catchment level, at sub-regional/island or country level, at full regional level?

4. Assessing and synthesizing **scientific and/or policy/management response**:

- What is the current status of response taken on scientific or policy/management level against the major coastal issues in the region?

5. Assessing and synthesising **gaps in understanding, hot spots and research needs**:

- What are the major gaps in our current understanding of river catchment – coastal sea interaction in the region of concern and which hot spots should be addressed in a future integrated scientific effort/proposal (natural and socio economic disciplines)?

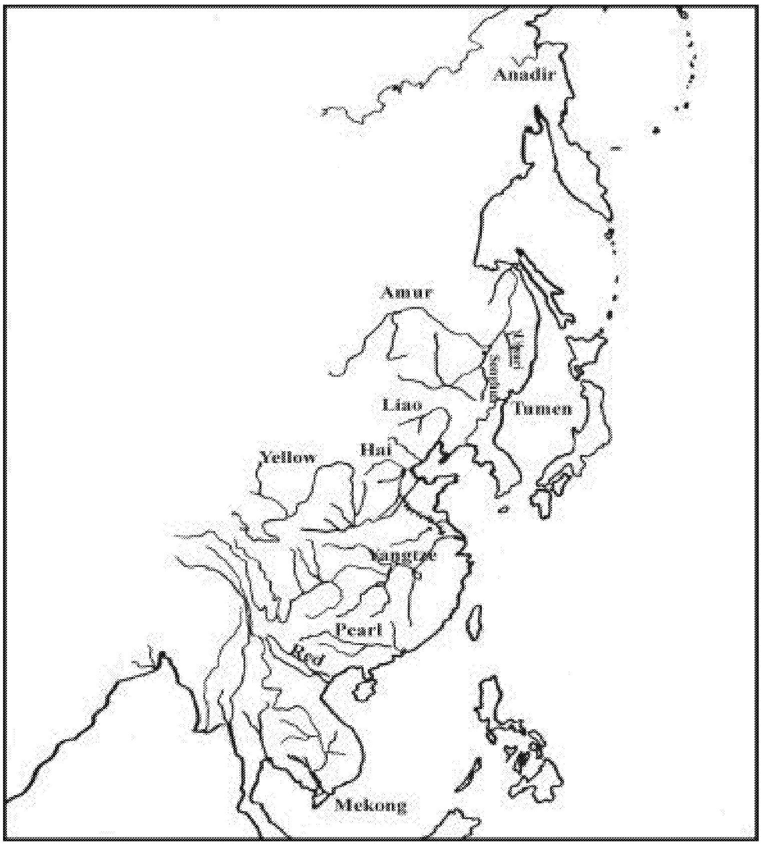


Figure 1.3. Some of the major rivers evaluated in terms of issues, pressures, drivers and land-based activities.

The issues were evaluated for the river systems shown in Figure 1.3 and also for rivers located on Taiwan and in Japan. A huge variety of geological, climatic, land-use and land-cover patterns are represented. Most rivers in continental East Asia drain tectonically passive coasts, characterised by larger drainage basins and with sediment yields dependent on climate and human perturbations. The Yellow River, with a drainage basin area of 745×10^3 km^2, yielded 1199×10^6 t yr^{-1} of sediment before 1963 (areal sediment yield of 1610 t km^{-2} yr^{-1}). Since 1986 water discharge has been reduced by as much as two-thirds of that prior to 1963, and sediment transport to the coast has been halved. Small rivers in Taiwan and Japan drain tectonically active areas. For example, the Lanyang-His River, with a small drainage basin of 820 km^2, yields up to 93,000 t sediments km^{-2} yr^{-1}, making it one of the top ten rivers in the world in terms of sediment yield.

The major coastal issues, pressures, drivers and land-based activities in the three sub-regions were identified in the workshop:

Area 1 - Vietnam and South China

(i) a long history of agriculture-based economy, with intensive rice and crop production, fish and shrimp culture. The landscape of the catchment areas was modified hundreds of years ago e.g., the dyke pond systems.

(ii) rapid socio-economic development (South China for about 20 years, Vietnam for about 10 years).

(iii) urbanization and industrialization along coastal areas leading to increased discharge of domestic and industrial effluent has exerted harmful effects on environmental and human health e.g., red tides.

(iv) chemical fertilizers have replaced traditional organic wastes for agriculture and aquaculture and the use of pesticides and antibiotics has further aggravated the problem.

(v) deforestation was a problem some 40 years ago, but it does not seem to be a major problem at present.

Area 2 - Central China, Japan, Taiwan and Korea

(i) the Yellow River delta is subject to severe erosion due to reduced sediment discharge, mainly as a result of reservoir construction and diversion of river water.

(ii) the Yangtze River delta is threatened because of the local groundwater pumping and construction of dams.

(iii) eutrophication is a generic problem. Agriculture, urbanization, deforestation, domestic and industrial discharges are the major drivers.

(iv) the incidence of red tide has increased while fisheries and biodiversity have suffered.

(v) sea level rise due to global warming accompanied by land subsidence due to excess ground water pumping is a threat on the horizon.

(vi) scientific approaches to ameliorate the above mentioned problems, such as environmental assessment, have been applied to help in coastal zone management.

Area 3 - the Russian Far East - covers the vast area of the Far East of the Russian Federation. The receiving water bodies are the Bering, Okhotsk and Japan seas. The vast area is less populated than the southern and central regions of East Asia. In general, the major drivers are agriculture, mining and deforestation in the northern part, and agriculture, deforestation, urbanization and oil production in the Amur River catchment. Floods, agriculture and fisheries affect the coastal zone slightly. On the Kamchatka Peninsula, gold mining and deforestation cause sediment pollution and change the sediment transport and coastal erosion patterns. On the northern coast of the Sea of Okhotsk there are few settlements, so human impact on the coastal zone is insignificant. However, to the south, some significant impact is associated with the Amur River. Mining, for gold on the land and oil/gas mining on and near Sakhalin Island on the shelf, is intensive. Floods occur every year. Chemical pollution by pesticides and heavy metals also occurs. On the Sea of Japan coast, to the north of Peter the Great Bay, localized intensive contamination of sediment due to mining occurs. From Peter the Great Bay to the Russia/Korea border, chemical pollution in sediment by hydrocarbon and river discharge (heavy metals) occurs in coastal embayments. Pollution is also associated with the Tumen River (organic pollution of the sediment from China side and mining from North Korea in summer). In the estuary, eutrophication and red tides occur. The ocean currents are directed towards the north from the south, which causes accumulation of nutrients and red tides in late summer. Coastal erosion may be a secondary problem. Along the Japanese coastline, mining is a dominant activity which affects the coastal zone.

Demonstration sites (a tentative compilation)

During the workshop, sites for key case studies were suggested, drawing on current understanding. Gaps were identified, for example the serious lack of systematic monitoring, particularly for the Mekong, Red, and Amur rivers. Possible demonstration sites for key case studies are listed in Table 1.2.

Table 1.2. Possible demonstration sites for key case studies.

Area location/ Sub-region	Major rivers	Major coastal issue	Major driver
1	**Mekong and Red rivers**, Vietnam	Erosion and flooding	Climate and dams
1	**Pearl River,** China	Eutrophication/ Pollution	Agriculture/ aquaculture/ urbanization/industrialization
2	**Yellow River**, China	Reduction of freshwater and sediment discharge	Dams
2	**Yangtze River**, China	Cut off of freshwater discharge/ Eutrophication/ecosystem change in East China Sea	Land use change/dams /Western development
3	**Amur River, Russia**	Contamination	Mining/urbanization/ agriculture
3	**Tumen River,** North Korea/ China/Russia	Contamination	Future Development
1-3	**Small catchments** in the sub-tropical central and northern sub-region *	As above	As above but resulting in even more pronounced observed coastal impact and dominating wide areas of the coastal zone (see for example Vietnam)

*= The small and medium catchments located in the southern and northern regions of East Asia, whose inputs dominate wide stretches of the coastline, have not received adequate scientific monitoring until very recently. Therefore, there is not yet enough river data to quantitatively assess the coastal issues and natural and anthropogenic activities driven from these catchments – an aspect which should receive priority attention in future East Asia Basins research. Other than that, the selection presented provides an expert-based list of key issues and climatic regions, and thus classes of catchment/coast regimes characterising the sub-regions. However, due to non-homogeneous data availability and quality, an **EastAsiaBas** future proposal should delineate clearly where it can be built upon existing information and where primary investigations should be focused on establishing the database required. Synergistic links to existing or upcoming research in the broader LOICZ framework (i.e. regional "Cat" = Catchment/Coast and Human Dimensions studies such as EuroCat - http://www.iia-cnr.unical.it/EUROCAT/project.htm) need to be elaborated, and a close watching brief kept on the LOICZ Basins website (http://w3g.gkss.de/ projects/loicz_basins/ or via www.nioz.nl/loicz/) to develop a regional East Asian effort along the lines of the global LOICZ-Basins core project and its related projects.

2. REGIONAL ASSESSMENT AND SYNTHESIS: EAST ASIA

by G.H. Hong, H.H. Kremer and W. Salomons

2.1 Aims and objectives of the workshop

Most studies of environmental impacts on coastal ecosystems deal with activities occurring at the coast. Less attention has been paid to activities occurring within catchment basins and their potential to impact on coastal areas. Study of these impacts and the need to cope with their adverse ecological effects has resulted in a multidisciplinary approach to assessment, analysis and trend modelling of the pressures, state changes and impacts (Lacerda *et al.* 1999).

Most legislation regarding environmental conservation, management and the sustainable utilisation of coastal natural resources fails to consider human activities in catchment basins, sometimes far from the coast. The socio-economic driving forces acting on river catchments may be completely different from those acting on coastal areas. A general problem is a scaling mismatch of coastal issues and legal instruments, drivers of change and legislation rather than low-quality environmental laws (Kremer and Köhn 2000). As a result, although many coastal areas around the world have witnessed a strengthening of environmental regulations, any potential beneficial effects of these regulations on the quality of coastal environments are being overtaken by detrimental impacts generated in catchment basins (Salomons *et al.* 1999).

The LOICZ-Basins project assesses coastal change from a system perspective, and takes observed effects as a reflection of pressures within the whole catchment basin. It is recognised that coastal change is forced both by land-based processes and global forces which affect the material cycles and thus the horizontal fluxes reaching the coast. The priority focus in LOICZ-Basins is the transport of water and sediments and the cycling of carbon, nitrogen and phosphorus. Of particular interest is the residual transport of these materials as generated by sectoral activities such as agriculture, urbanisation, industrial production or damming. The information can be used to derive critical fluxes, loads and concentrations to enable scenario and carrying capacity analyses based on current status and expected pressure trends. The approach can easily be adapted to other substances and situations. This report is the outcome of the LOICZ assessment and synthesis workshop held in Hong Kong SAR, China, 26-28 February 2001 dealing with catchment basin/coastal sea interactions in East Asia.

The guiding questions were:

- What are the major impacts on the coastal zone?
- How close are they to a critical threshold of system functioning?
- What are the major driver/pressure settings at catchment level causing coastal change?
- Can we identify spatial scales on which certain driver/pressure settings dominate coastal issues?
- What are the major pressure/driver settings at catchment level causing the observed coastal impact and what are the future trends?
- What are the major pressure/driver settings at sub-regional or country level causing the coastal impact observed and what are the future trends?
- What are the major pressure/driver settings at regional or continental level causing the coastal impact observed and what are the expected trends?
- What is the current status of response taken on scientific or policy/management levels against the major coastal issues in the region?
- What are the major gaps in our current understanding of river catchment-coastal sea interaction and which hot spots should be addressed in a future integrated scientific effort (natural and socio-economic disciplines)?

A detailed description of the DPSIR framework is provided in Appendix I.

2.2 Major and minor catchments in East Asia

To enable an appropriate ranking of Driver/Pressure influence, we have chosen to evaluate the major rivers and coastal areas from activities in the drainage basins. Examples of different river types and their major hydrographic characteristics are listed in Table 2.1 and shown in Figure 2.1.

While most coasts of East Asia are passive coasts, the coasts of Taiwan and Japan are active coasts with small drainage basins, and with high water and sediment discharges fed by high sediment yields. Smaller drainage basins have less area to store sediments, so that the sediment yield of smaller basins increases as much as 7-fold for each order of magnitude decrease in basin area. The result is that many rivers draining smaller basins can discharge far more sediment to the sea than a single river draining a much larger basin. Rivers draining only 10% of the world's drainage basins account for more than 60% of the sediment discharge to the ocean (Milliman 1991).

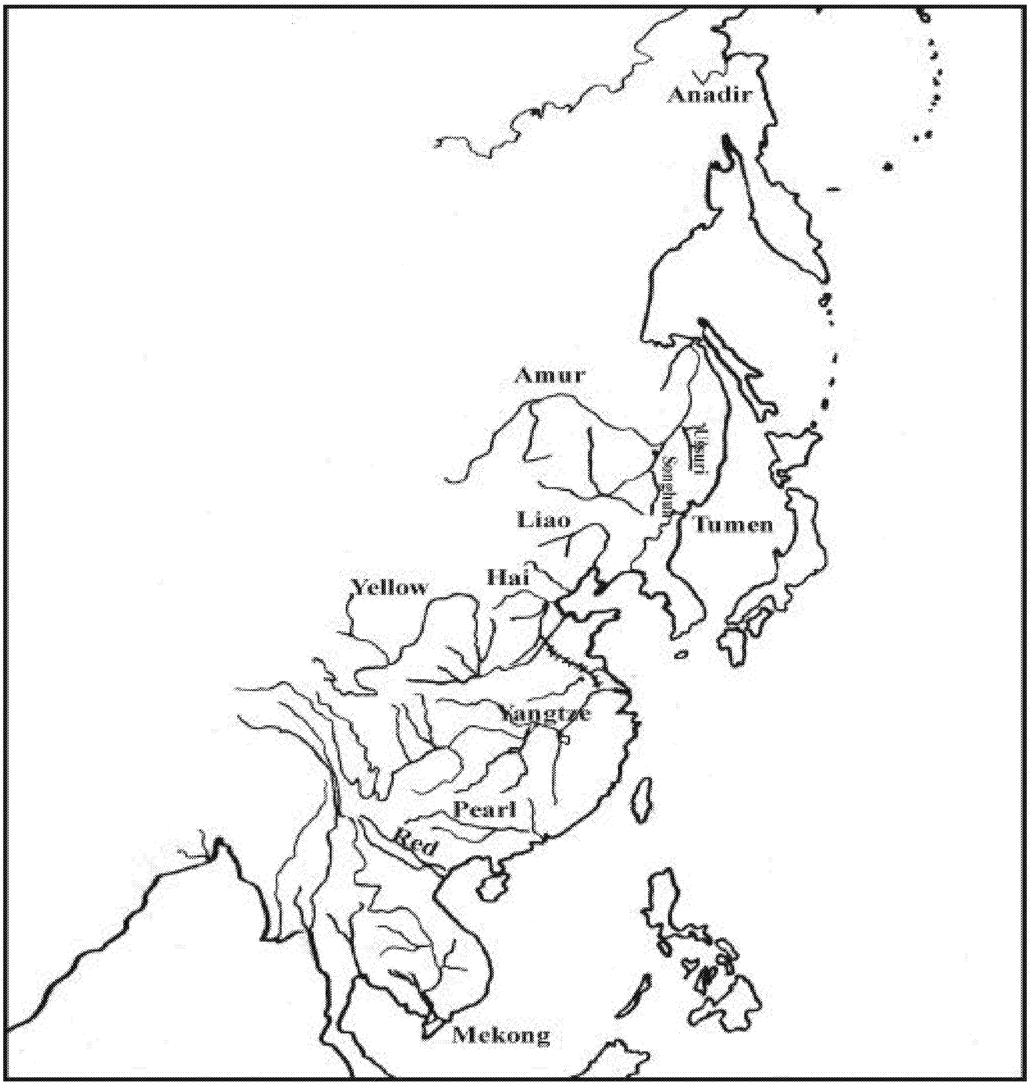


Figure 2.1. Some of the major catchments in East Asia addressed in the regional LOICZ-Basins assessment.

Table 2.1. Examples of East Asian drainage basin types based on catchment size, including water discharge, sediment load, calculated yields and receiving coastal sea. The rivers may be divided into the three size classes of small (areas less than 10,000 km^2), medium (areas 10,000 to 200,000 km^2) and large (basins greater than 200,000 km^2) rivers.

River (basin classes) – L = Large M = Medium S = Small	Basin size class	Basin area (10^3 km^2)	Water discharge ($10^9 m^3 yr^{-1}$)	Sediment load (10^6 t yr^{-1})	Sediment yield (t $km^{-2} yr^{-1}$)	Receiving coastal sea
Mekong, China/Myanmar/ Laos/Thailand/ Cambodia/ Vietnam	L	795	448	187	235	South China Sea
Red, Vietnam	L	190	137	116	611	South China Sea
Pearl, China	L	450	330	70	156	South China Sea
Yangtze, China	L	1950	896	500	241	East China Sea
Yellow, China	L	745	47	410-1100	550-1610	Bohai
Haihe, China	L	270	256			Bohai
Amur, China/Russia	L	1855	394	20	11	Sea of Okhotsk, Sea of Japan
Anadir, Russia	L	191	60			Bering Sea
Minjiang, China	M	61	62	9	142	East China Sea
Yalujiang (Aprock), China/Korea	M	63	38	5	77	Yellow Sea
Han, Korea	M	26	21	12	474	Yellow Sea
Kum, Korea	M	10	6	4	400	Yellow Sea
Nakdong, Korea	M	24	9	3	639	Korea Strait
Tumen, China/Russia/N. Korea	M	33	5	3	91	(Sea of Japan
Lanyang-Hsi, Taiwan	S	0.8	1.8			Off Taiwan
Erhjen, Taiwan	S	0.1		13	93000	Off Taiwan
Tseng-wen, Taiwan	S	1.2	2.4	31	26470	Off Taiwan

2.3 Biophysical sub-regions

The Indian Plate has migrated to the north and collided with the Eurasian Plate, resulting in the Himalayas uplift, blocking the circum-global atmospheric circulation and creating the East Asian Monsoon, which is characterized by wet summers and dry winters. The climate in East Asia has become arid with sparse vegetation in the west, wetter in the east. Rainfall is generally high in the south and low in the north. Along the south- north axis of its coastline East Asia encompasses a wide range of climatic zones ranging from tropics to arctic tundra.

The East Asian sub-continent is dominated by a number of very large river catchments and wetlands east and south of the Himalayas, east of the Ural Mountains and east of the Kolyma Ranges, which influence broad areas of the regional coastal zone. Considerable parts of the coastline are, however, influenced by relatively small and medium catchments. Coastal waters adjacent to East Asia are all marginal seas of the Western North Pacific: the South China Sea, East China Sea, Yellow Sea and Bohai, Sea of Japan (East Sea), Sea of Okhotsk and Bering Sea. Due to the large freshwater input, shelf regions of the marginal seas are strongly influenced by the rivers in terms of catchment-derived water and material. Therefore, the interaction of natural and anthropogenic activities in the river catchments are strongly coupled to the ecosystem and oceanographic characteristics in the receiving marine waters of the marginal seas.

Anthropogenic pressures also vary within East Asia although most East Asian rivers have been strongly altered through human activities or are subject to management plans affecting land and water use. There is extensive and intensive agriculture and aquaculture with a large population in the southern tropics, agriculture and industrial development with a large population in the temperate region, and terrestrial mining and offshore oil and gas exploitation with a sparse population in the cold temperate and arctic regions (see Figures 1.2, 2.1).

Relatively recent developments and anticipated further alterations to catchments pose mounting concerns about the issue of environmental functioning along East Asian water cascade (including the coastal seas). Since the cessation of major wars in the region, demographic pressure on the coastal zone is increasing and heavily populated areas keep expanding due to accelerated economic development in the coastal regions. Regional cooperative mechanisms needed to deal with complex trans-boundary rivers have not been established yet.

A sub-regional classification was applied during the assessment and in order to select hot spots for East Asia, delineated by natural climatic and catchment characteristics and taking into account different anthropogenic use patterns paralleling this zonation. The three sub-regions are:

- Area 1: the coast of the South China Sea along Vietnam and South China from ca. 7°N to the Tropic of Cancer, corresponding to the high rainfall region. The coasts are embedded with the mouths of the Mekong, Red and Pearl rivers, plus numerous medium and smaller rivers.
- Area 2: the coast of the East China, Yellow and Bohai seas, stretching from the Tropic of Cancer to the ca. 41°N. These coasts have a temperate climate and are embedded with the mouths of the Yangtze, Yellow (Huanghe), Hai and Liao rivers with numerous medium and small rivers along the coasts of China and the Korean Peninsula. The tectonically active subtropical island of Taiwan is also included here, as are the Japanese islands, due to the similar intensive human alteration of river catchments and coastal zone developments.
- Area 3: the coasts of the Sea of Japan, Sea of Okhotsk and Bering Sea correspond to the cold and relatively arid climate from ca. 33°N to the Arctic Circle (66.33°N). The coasts in the sub-region are embedded with the mouths of the Amur and Anadir rivers with medium and smaller rivers along the coasts of Siberia, Korea and Japan.

Area 1: South China Sea.

Mekong and Red River catchments

The two large rivers, Mekong and Red, plus 114 smaller rivers disgorge into the South China Sea along the Vietnamese coast. The Mekong River descends from the Tibetan plateau in China (Tibet Autonomous Region and Yunnan Province), runs across Myanmar, Laos, Thailand, Cambodia and finally enters Vietnam. There are three sections of the Mekong River: high, middle and low. The low section is the end of the Mekong River running from Phnom Penh to the South China Sea, a distance of 340 km with a slope of about 2.5 m km^{-1}. Entering Vietnam, the Mekong River divides into an eastern branch called the Mekong River and a western branch, the Bassac River; it flows into the South China Sea by nine distributaries. The 50 million residents and countless river and floodplain biota of the basin depend on the Mekong's annual flood-drought cycle. The total catchment area of the Red River including the Thai Binh River is ca.

$0.19x10^6$ km^2 which is shared by China, Lao PDR and Vietnam. The river has three major tributaries of the Da, Thao and Lo-Gam.

The major drivers for the catchment changes are deforestation in the upper reaches of rivers, destruction of mangrove swamps, dike and dam building, channel dredging, agriculture, aquaculture, concentration of economic development and high population density in the catchment basins. These drivers modify supply and distribution of water, sediments and nutrients. The regional information is largely taken from Than *et al.* (this report) and Tri (this report). The regional climate is humid tropical and dominated by monsoons: a dry season (December-April) and a wet season (May-November). The annual precipitation is about 1700 mm in the delta and concentrated more than 90% in the wet season. Heavy rainfall in the wet season causes flooding of the river and it peaks in October (Minh *et al.* 1997). Forest in the upper reaches of rivers has been reduced from 43% in 1943 to 28% in 1995. In the delta, the temperature is relatively uniform with an average of 27-30°C and annual evaporation is 1020-1240 mm (Nguyen *et al.* 2000).

Table 2.2. Characteristics of water discharge and sediment yield of some rivers emptying into the South China Sea in the southern sub-region of East Asia.

River	Length (km)	Drainage basin (km^2)	Water discharge ($10^9 m^3 yr^{-1}$)	Sediment discharge ($10^6 t\ yr^{-1}$)	Sediment yield ($t\ km^{-2}\ yr^{-1}$)
Mekong	4,880	795,000	448	187	235
Red	1,140	190,000	137	116	611
Pearl	2218	450,000	330	70	156
Hanjiang, Guangdong			24	7	

The total population of Vietnam is 77 million, with 42% of the total population in coastal areas. The population density ranges from 50 to 2,000 ind. km^{-2} in the mountains and coastal city areas, respectively. The Mekong River Delta (15 million people) and Red River Delta (17 million people) are important rice cultivation areas in the southern and northern Vietnam, accounting for the 50 and 20% of the national rice production, respectively. The average birth rate fell from 2.8 in 1990 to 1.7% in 1998. However, the highest percentage of population pyramid belongs to ages of 1 to 9. The regional economy is expected to grow rapidly, as much as 5-7% annually.

Water is in great demand for rice production. About 60% of the total cultivated land ($7x10^6$ ha) is water-demanding paddy fields. $47x10^9$ m^3 of water were used for irrigation in 1990. The demand of irrigation is most pressing in dry periods, for example in RRD, irrigation of rice paddy draws as much as 20-50% of river discharge, which significantly reduces the river discharge in the lower reaches.

Agriculture depends heavily upon chemical fertilizers and pesticides, some $2.1x10^6$ tonnes of chemical fertilizers ($1.2x10^6$ tonnes of urea, $0.793x10^6$ tonnes of phosphate, $0.022x10^6$ tonnes of potassium) were applied in 1993. The application rate of chemical fertilizer is 0.3 t ha^{-1}. Some $20x10^3$ tonnes of pesticides (DDT, Lindane, Monitor and Wofatox) were applied. The application rate of the pesticides is 2.9 kg ha^{-1}. Pesticide residues are transported by rivers to the coastal zone where they accumulate in the bottom sediments and aquatic organisms. The concentrations of DDT congeners in carp are reported to be greater than the maximum permissible concentrations in food covered by European standards (Nhan *et al.* 1998).

Pearl River catchment

The Pearl River is the third largest river in China and its delta lies in the subtropical zone with a long summer, a short winter and an annual temperature of 21-22°C. The total rainfall is 1600-2000 mm yr^{-1} with 80% of the river's annual discharge in the wet season (April to September). Winds are southerly in summer and northerly in winter. Typhoons coincide with the wet season and hence flooding is common, especially near estuaries. Climate change in the region is pronounced. The annual freshwater discharge into the estuary has increased as much as 51 m^3 s^{-1} (0.5% of total river discharge) from 1959 to 1984, and the sea level has risen as much as 1.7-1.9 mm yr^{-1} (Wu, this report). The Pearl River delta is flat and fertile land of rich biological diversity with abundant freshwater and easy access to the sea for agricultural and aquacultural development. It is renowned for crop and fish production. The total population was 21.2x10^6 in 1995. The major cities are Guangzhou, Shenzhen, Zhuhai, Foshan, Zongshan, Dongguan, Huizhou, Jiangmen, Hong Kong Special Administration Region (SAR) and Macau SAR.

Area 2: East China Sea, Yellow Sea , Bohai Sea and Taiwan Island

East China Sea, Yellow Sea and Bohai Sea

The Changjiang and the Huanghe (Yellow) rivers, the two largest rivers in East Asia, discharge into the East China Sea, the Yellow Sea and the Bohai Sea as do other smaller rivers (Table 2.3). The Yangtze headwaters are in the Qinghai-Xizang Plateau in Tibet but the river flows mainly through a carbonate platform in its lower reaches. The Huanghe originates in the foothills of the Bayan Khran Mountains in Qinghai Province, flows through an arid mountainous region and drains a loess-covered terrain containing abundant soil carbonate and evaporites. The Yalujiang forms the border between China and North Korea. The river gathers its water from the Changbai Mountains in a well-developed temperate deciduous forest and flows through an extensive agricultural area in the middle and lower reaches. In the lower part of its course the river receives a considerable amount of wastes from both non-point and point sources. River discharge is dominated by the Chinese continent, with much less contributed by the Korean Peninsula.

Table 2.3. Characteristics of water discharge and sediment yield of some rivers emptying into the East Asian Coastal Ocean from the contiguous continent.

River	Length km	Drainage basin km^2	Water discharge 10^9 m^3 yr^{-1}	Sediment discharge 10^6 t yr^{-1}	Sediment yield t km^{-2} yr^{-1}
Han	827	26x10^3	20.9	12.4	474
Keum	401	10x10^3	5.8	4.0	400
Yeongsan	116	3x10^3	2.1	1.2	443
Anseong	76	2x10^3	1.1	0.7	389
Sapkyo	65	2x10^3	1.2	0.7	389
Mankyong	99	2x10^3	1.1	0.6	400
Dongjin	45	1x10^3	0.7	0.4	397
Seomjin	225	5x10^3	3.2	3.1	639
Nakgdong	526	24x10^3	9.2	12.1	507
Huanghe (1953-1963)	5400	745x10^3	47.2	1100	1610
Huanghe (1986-1992)			17.0	410	550
Changjiang	6300	1,950x10^3	895.6	500	241
Huaihe	1000	270x10^3	25.7		
Minjiang	577	61x10^3	62.4	8.7	
Aprock (Yalujiang)	803	63x10^3	37.8	4.8	77

The atmospheric pathway is also a significant conduit for the transport of terrestrial material to the sea in East Asia due to the presence of persistent westerly winds and the arid Gobi/desert areas and loess region. In the Yellow Sea proper, the average sediment accumulation rate is ca. 250 g m^{-2} yr^{-1} of which 50 g m^{-2} yr^{-1} is delivered through the atmosphere (Zhang *et al.* 1993). In the more remote Sea of Japan, atmospheric dust flux is estimated to be 10 g m^{-2} yr^{-1}. River input is mostly confined in the river mouth and estuarine area, but atmospheric input operates over the entire sea, especially the Yellow Sea and the Sea of Japan proper, which are away from the direct influence of the rivers.

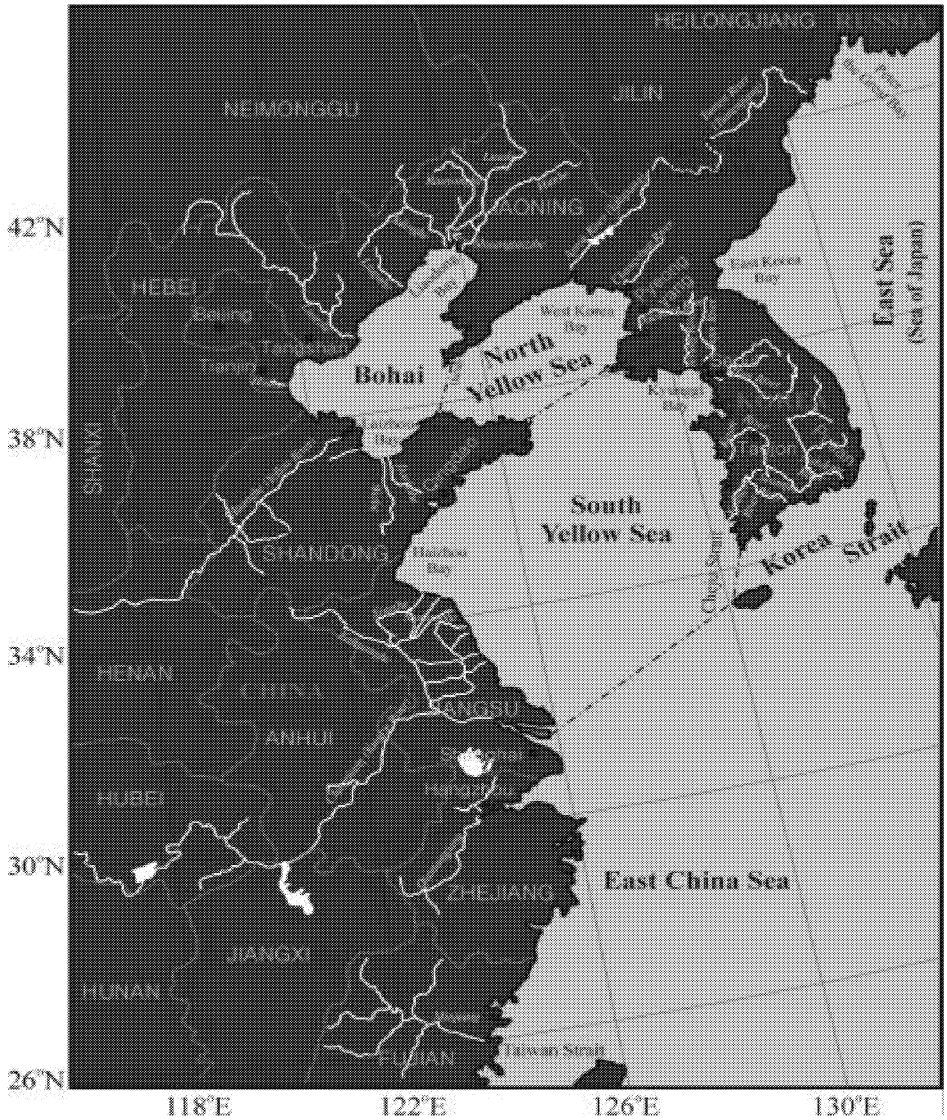


Figure 2.3. Detailed map of the watersheds and rivers emptying into the East China Sea, Yellow Sea and Bohai Sea.

Taiwanese rivers

Small rivers in the western Pacific Ocean contribute an enormous amount of sediments to the ocean (Milliman 1991) due to the active tectonic processes of uplifting and high precipitation. Taiwan has very similar conditions to Oceania, such as high sediment yield compared to the water discharge, and cyclone-originated torrential rain. Some of the Japanese islands in the tropics would belong to the same category. The Taiwan orogeny is the result of arc-continent collision between the Philippine Sea plate and the Chinese continental margin that began about 4-5 million years ago. The Holocene river history of the Erhjen River, a good example of Taiwanese rivers, has revealed river responses to climate change and tectonic activity (Hsieh and Knuepfer 2001). The Taiwanese subtropical forest, in mountains typically above an altitude of 3000 m, receives a mean annual precipitation of 3000 mm. The mean water runoff is 2200 mm. On average, 38% of the runoff is derived from summer rain related to typhoon events and 41% from precipitation during the north-east monsoon from September to April (Kao and Liu 2000). More than half of the particulate organic carbon and nitrogen fluxes from the Taiwanese islands may have been humanly induced. Landward migration of the shoreline has occurred at the mouth of the Tseng-wen River due to sediment deprivation after reservoir construction in the upper reaches of the river in 1974. By 1995, over 80,000 m^3 of sediments were trapped in the reservoir River (Liu *et al.* in review). The timing of the trend reversal from shoreline accretion to shoreline retreat at the river mouth coincided with the completion of the Tsen-wen Reservoir.

Recent increases in industrial and commercial activities along the coastal zone of Taiwan have resulted in modifications to the coastline due to coastal engineering works, which have become a part of the landscape. However, misplaced coastal engineering structures may destroy or reduce the effectiveness of neighboring natural and engineered structures leading to coastal disaster. Lin (1996) has reviewed coastal modifications due to human influence in south-western Taiwan.

Table 2.4. Characteristics of water discharge and sediment yield of some rivers in Taiwan. (Data from Water Resources Bureau 2000).

River	Length Km	Drainage basin area km^2	Water discharge $10^9\ m^3\ yr^{-1}$	Sediment discharge $10^6\ t\ yr^{-1}$	Sediment yield $10^3\ t\ km^{-2} yr^{-1}$
Lanyang-Hsi	70	820	1.81		
Erhjen R.		140		13	93
Tsengwen R.	138	1176	2.4	31	176
Choshui R.	186	3155	6.1	64	203
Kaoping R.	171	3257	8.5	36	11
Tanshiu R.	159	2726	7.0	11.5	4
Taichia R.	140	1236	2.6	4	3
Wu R.	117	2026	3.7	6.8	3
Yenshui R.	87	222	0.3	2.3	10
Peinan R.	84	1603	3.7	24	23
Peikang R.	82	645	1.0	2.4	4

Area 3: The Sea of Japan, Sea of Okhotsk, Bering Sea

Watersheds of the northern regions in East Asia, comprising the rivers emptying into the Sea of Japan, Sea of Okhotsk and Bering Sea are very different from the other regions in terms of human impacts since the region is scarcely populated. Therefore, human impact on the coastal sea is negligible or highly localized in the few coastal cities.

Sea of Japan
The largest source of freshwater to the Sea of Japan is thought to be the Amur River, which enters the sea through Nebel'sky Strait although no measurements exist of either the net flow or the Amur flow through this strait (Martin and Kawase 1998).

The Tumen River (Tumenjiang) is a boundary system between China, North Korea and Russia. It rises in the northern part of the Paektu (Changbai) Mountains at an altitude of ca. 1500 m. The river traverses north-eastward to Tumen city and then flows south-eastwards until it empties into the Sea of Japan. Over the drainage basin, rainfall averages 500-600 mm, and the frozen period is 100-120 days yr^{-1}. Two floods occur, in April due to the spring thaw and in July-August due to the monsoonal rain. Several large tributaries join the main stream in the middle and lower reaches from China. In the upper reaches, the river flows through a forest region with a low population, where the riverbed slope may be 7.2 and flow rate may reach 5 cm s^{-1}. The vegetation is characterized by temperate deciduous forests developed over basalt. In the middle reach between Nanping and Yingan, the riverbed slope reduces to 1.8 over a distance of 215 km. The middle reach has a dense population, rapid advance of industry and intensive agriculture. In the lower part of the drainage area, the river moves over the fluvial plain, and the channel is open to navigation for a distance of ca. 150 km. The population in the drainage basin on the Chinese side is estimated at ca. $1x10^6$, which is distributed mainly in several cities and their suburban regions within the middle and lower reaches, such as Yanji, Tumen and Hunchun. Industry within the watershed includes engineering, chemistry, material processing, papermaking, rubber, textiles and printing. Corn, wheat and beans are the main agricutural products in this region. As a result of the rapid population increases and industrialization within the watershed, human and urban wastes drainage must be affecting river water quality and hence the health of the marine environment in adjacent coastal waters (J. Zhang, 2000, personal communication). The influence of the Tumen River discharge is limited to within 5-10 miles from the mouth and in the surface layer to a depth of less than 10 m, even during the typhoon period (Tkalin and Shapovalov 1991).

The Tumen River Economic Development Area (TREDA) is experiencing a rapid economic and industrial growth with manufacturing and food processing industries, development of mining and energy production which is supported by UNDP through the Tumen River Area Development Program (TRADP) (Figure 2.4). To ensure sustainable development of the region, increased attention needs to be given to environmental protection and to sustainable management of resources. This was recognized in the early stages by the member states who in December 1995 signed the Memorandum of Understanding on Environmental Principles. Considering its abundant natural resources, its human resource potential, and the political will of all parties concerned from government and private sectors, this area may become one of the largest international development projects, with the long-term potential to attract billions of dollars in investments for infrastructure, natural resource development, industry, oil exploration and urban development. UNDP has been assisting initiatives of the five concerned countries (the People's Republic of China, the Russian Federation, Mongolia, the Democratic People's Republic of Korea (DPRK) and the Republic of Korea (ROK) to elaborate and coordinate policies and actions for economically and environmentally sustainable development of the region since 1992. In this context, it is the aim of the TRADP to create favorable conditions for natural and foreign investments, to reinforce regional cooperation for the development of infrastructure and communication systems, to coordinate programs for human development, and to adopt policies and initiate actions for environmental protection and effective management of common ecosystems (GEF-UNDP 1997).

Figure 2.4. Detailed map of the Tumen River Development Araa (TREDA).

Peter the Great Bay has two inlets, Amursky and Ussurisky bays, separated by the Muravyov-Amursky Peninsula. The characteristics of the drainage basins of the two bays are different. The average annual surface runoffs from the adjacent land mass to Amursky and Ussurisky Bay are 92 and 25 m^3 s^{-1}, respectively, for the recent decades. Other rivers flowing into the Sea of Japan are very small in terms of water and sediment discharge (Table 2.5; Hong *et al.* 1997).

Table 2.5. Characteristics of water discharge and sediment yield of some rivers emptying into the South China Sea in the southern sub-region of East Asia (data from Hong *et al.* 1997 and other sources).

River	Length km	Drainage basin area km²	Water discharge 10^9 m³ yr⁻¹	Sediment discharge 10^6t yr⁻¹	Sediment yield t km⁻² yr⁻¹
Bering Sea					
Anadyr	1,117	191,000	60		
Sea of Okhotsk					
Amur	4510	1,855,000	394	20	10.8
Sea of Japan					
Rudnaya					
Radzolnaya	516	33,168	5.1	3	90.5
Tumen			2.9	0.05	
All other North Korean rivers			8.1	0.068	
Taewha			0.4	0.009	
Hyungsan			0.8	0.002	
Yeongduck Oshipchun			0.1	0.0001	
Samchuk Oshipchun			2.7	0.003	
Kangrung Namdaechun			1.7	0.005	
Yangyang Namdaechun			3.3	0.002	
Ishikarigawa			12.8	0.35	
Shinanogawa			16.7	0.45	
Aganogawa			12.3	0.11	
Moganigawa			12.7	0.25	
Teshiogawa			5.9	0.08	
Omonogawa			7.9	0.07	
Yoneshirogawa			5.7	0.05	
Gournogawa			5.9	0.05	
Kuzuryugawa			4.3	0.04	
Jintsugawa			5.9	0.02	
Iwakigawa			2.8	0.06	
Hiigawa			1.8	0.02	
Yuragawa			1.7	0.01	
Shirbetsugawa			2.0	0.10	
Shougawa			1.2	0.10	

Sea of Okhotsk
Amur River

The Amur River, the world's ninth largest river, stretches from the grasslands of Mongolia to the Sea of Okhotsk. The Amur River and its southern tributary, the Ussuri River, define the border between Russia and China. The Amur Basin is the meeting place of Palearctic and Oriental biogeographic regions. The territory of the Amur River basin is populated by some 5.5 million Russians and 70 million Chinese (http://forest.org/archive/europe/ecforume.html). The Amur region is the only place in Europe and Asia where biotas of the taiga and subtropical forest coexist. Here the boreal forests from the north mix with broad-leafed forests from the south, creating a mosaic of outstanding biodiversity that includes Siberian Tigers, Oriental Leopards, Great Siberian Sturgeons, Oriental White Storks, Hooded Cranes and other rare and endangered species. The Three Rivers Plain, where the Amur, Ussuri and Songhua rivers meet, is the intensive agricultural basin known as the Chinese northern food basket.

Ice forms in the Amur in the second half of October. The upper reaches become icebound at the beginning of November, the lower reaches in the second half of the month. The lower sections open at the end of April and the upper sections in May. Ice jams often occur in the sharp bends of the river, temporarily raising the water level by as much as 17 m. Above the confluence with the Songhua River, the water in the Amur is relatively clear, but below that point it becomes muddy. The average annual sediment loads is some 20 $x10^6$ tonnes (Encyclopedia Britannica).

During the past decade, economic crisis led to a three- to four-fold increase in agricultural production in the Amur region. Poor farming practices such as burning straw and extensive use of herbicides and pesticides have damaged the soils, wildlife, human health and the economy.

Large areas of the world's boreal forest zone, which natural fire has shaped over millennia, are also burned annually (Cahoon *et al.* 1987). Industrial and recreational use of the boreal forest has increased dramatically over the past century, along with forest fire suppression capabilities. However, periodic extreme fire weather events ensure that fires continue to be common. The fires that developed in north-eastern China and south-eastern Siberia in the spring of 1987 are a recent example of this process.

The climate in the extreme north-eastern region of China and in south-eastern Siberia, within the Amur catchment basin, is continental cold temperate, with long, cold, dry winters and short, warm, humid summers. In the winter the region is dominated by the Asiatic High, which forms over the Lake Baikal region and blocks the progression of winter storms. The infrequent winter storm passages produce relatively little precipitation, with most of the region receiving less than 5 mm. As spring approaches and warming begins, the Asiatic high breaks down and storm passages occur in rapid succession from west to east. These storms (and frontal systems) bring strong winds and little precipitation. When storm frequency increases, temperature rapidly increases and humidity remains low. This combination of conditions leads to the drying of forest fuels, creating a prime situation for fires. In the summer months the frequency of storm passages decreases, but the storm intensity increases. The greater amount of precipitation associated with the stronger storms reduces the fire hazard. The estimated trace gas emission based on the satellite assessment of burned area was $1.42x10^{14}$ g C of CO_2, $1.54x10^{13}$g C of CO, and $1.52x10^{12}$ g C of CH_4, which accounts for the 4 % of the global emissions of these trace gases.

The Okhotsk Sea is the one of the southernmost ice-covered oceans in the Northern Hemisphere. The inflow of freshwater from the Amur River suppresses the deep convection and promotes freezing. Assuming that the runoff water spreads out uniformly within the immediate area off the mouth of the river, the annual accumulation of freshwater will range from 2.6 to 5.0 m yr^{-1} (Ogi *et al.* 2000).

Bering Sea

The arctic is a climatically sensitive region (Hansen *et al.* 1983; Huh *et al.* 1998). General circulation models predict that the global warming effects of carbon dioxide and other greenhouse gases will be amplified two to four times in the arctic relative to lower latitudes. How fast and how far the weathering regime will respond are important questions (Huh *et al.* 1998). Possible changes in the fluxes of nutrients of silicon, nitrogen and phosphorus could affect primary productivity in the receiving marine basins.

The climate in the arctic lowlands is very severe, of the cold and arid continental type (Huh *et al.* 1998). It is winter for seven months of the year and snow-covered for 260 days on average. Mean July temperatures range from 12 to 16°C along the river valleys and <8°C in the highlands. Annual precipitation is about 600 mm on the coasts of the Bering and Okhotsk seas and lower in the inland. Along a thin strip of the coast, the vegetation is arctic tundra; the lowlands are largely tundra with forest tundra. The basins are pristine, comparable to Alaska in anthropogenic impact. Lack of extensive ice sheets in the Pleistocene, such as existed on the North American continent and in western Siberia, has led to the development of deep permafrost.

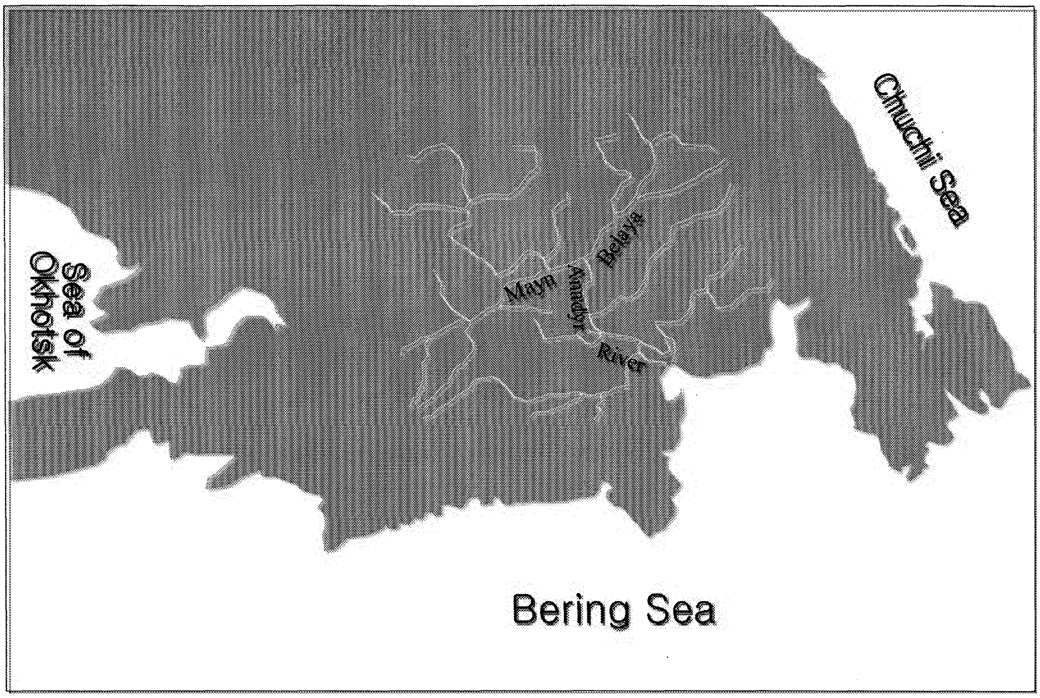


Figure 2.5. Detailed map of the Anadyr River.

The Anadyr River basin in north-eastern Siberia is an apparently pristine wastershed, lacking major industrial or agricultural activity. Mining is limited in the region. The Anadyr River is an Arctic river, straddling the Arctic Circle along much of its course. It is the second largest river emptying into the Bering Sea, through the Gulf of Anadyr. The course of the Anadyr River can be geographically divided into three sections. From its headwaters to its debouchment onto the central plain, the upper reach of the river is tightly constrained by mountainous terrain, is relatively shallow, and has steep stream gradients. In this area, the lithology is dominated by intrusive igneous rocks produced during the Alpine Orogeny. Between 170°E and 174°E, the middle reach of the river occupies a vast braid plain characterized by oxbow cutoffs and kettle lakes. In the middle of this zone the Mayn River joins the Anadyr from the south. The Belaya River, the other major tributary, joins the Anadyr at about 173°E (Figure 2.5). Beyond this confluence, the Anadyr is relatively deep, wide and well-constrained between high hills. High As and Sb levels are characteristic and can be attributed to the sulfide minerals in the drainage basin (Alexander and Windum 1999).

The hydrologic characteristics of the Anadyr River is such that significant flow is restricted to the period of mid-May through September when the region is ice-free, with a June peak during ice and snow melt and a shoulder due to a summer monsoonal rainfall in the form of intense storms. The headwaters thaw in mid-April and the ice-breaks up there several weeks earlier than in the lowlands leading to the formation of ice dams which can cause extensive flooding and channel migration. Extreme high flows occur in June (>3000 $m^3 s^{-1}$). The dissolved Si concentration at the mouth is 127 μM (Huh *et al.* 1998). The flux of dissolved material during the winter months (November - April) is about 20% of that during the summer.

2.4. Coastal issues, state changes, critical loads and ranking

Area 1: South China Sea

Mekong and Red Rivers

Morphology changes
Over 30% of the mangrove forests has been converted to shrimp aquacultural ponds in the delta regions, significantly changing the coastline. Mangrove forest has been reduced from 400,000 ha in 1943 to 170,000 ha in 1993 (Hong and San 1993, cited in Thanh *et al.* this report). As much as 24,000 ha of the tidal flood plain including mangrove marshes was reclaimed for agriculture between 1958 and 1995, and coastal land has accreted seaward. The Vietnamese coastline has been modified by building dykes (5700 km of river dykes and 2100 km of sea dykes) to protect the plains and inhabitants from river and sea floods over the last millennium.

Coastal mining for coal, sand, gravel and heavy minerals changes the morphology of the coastal landscape and subsequent dumping of solid and liquid waste degrades coastal water quality. In Quang Ninh Province alone $10x10^6$ tonnes of solid waste and $7x10^6$ m^3 of liquid waste has been dumped into the coastal zone.

The intensity and frequency of coastal flooding has increased in recent decades due to the combined effect of upstream deforestation, sea-level rise and blocking of waterways by the increased sedimentation at lagoon inlets and river mouths. Coastal erosion and accretion are rapid in the Mekong River delta (MRD) and Red River delta (RRD) and both pose threats to the coastal development. A quarter of the total coastline of both MRD and RRD has been subject to erosion, as much as 30-50 m yr^{-1}. Along the central sandy coast, erosion rate in general is 1-5 m yr^{-1}, especially Canh Duong, Thuan An, and Phan Ri areas. The accretion of the MRD and RRD has extended the coastline seaward as much as 150m yr^{-1}. Coastal erosion causes the loss of land and habitat for both human and natural biota. Coastal accretion causes the siltation of ports and harbours, as in Haiphong. Flood-related water freshening has caused loss of coastal fishery and aquaculture due to the blocking of coastal lagoons by longshore sand drift.

Landward saltwater intrusion occurs as far as 50 km in the Red River and 70 km in the Mekong River due to decreased river flow in the dry season and to tidal pressure. Decreased riverwater discharge due to dams and irrigation in the upper reaches of the rivers and to sea-level rise will lead to enhanced saltwater intrusion. The saltwater intrusion degrades coastal agriculture and aggravates the severe water shortage for domestic and industrial activities, especially in the central region of Huong River during the dry season.

Habitat loss and decrease of marine biodiversity
Recent natural and human-induced coastal land changes have led to the loss of tidal flats, mangrove marshes, beaches, seagrass beds and coral reefs. The mangrove marshes have been converted to agricultural land and aquaculture ponds or lost due to erosion. Beaches have been reduced by erosion and sand mining. Coral reefs and seagrass beds have been destroyed by the increased turbidity due to flood-originated silt and freshening of water. Loss of coastal habitats of estuaries, bays and lagoons along with increased pollution have degraded living resources for coastal and offshore fisheries. Some 98 species of marine fishes are reported to be threatened in Vietnam. The dams in the upper reaches interfere with spawning cycles by preventing fish migrations. The fish caught in the Mekong are the source of 40-60 % of the animal protein consumed by the population of the lower basin, and fish sustain an even higher percentage of people in much of Cambodia (Institute for Development Anthology 1998). The total annual catch of the lower Mekong River basin (Cambodia, Lao PDR, Thailand and Vietnam) alone is estimated to be 1.6 to 1.8 million tonnes, worth approximately $US1.4 billion (Poulsen and Jorgensen 2001). However, two species of migrating fish, *Clupanodon thrissa* and *Maerura reeversii,* have become rare and the breeding rates of other migrating fishes have been reduced by half after impoundment by dams in the Red River. Habitat loss and decrease of marine biodiversity have led to decreases in marine fisheries and to increases in disease levels in aquaculture species.

Pollution
Oil is the most prominent contaminant in Vietnamese coastal waters, while pollution from the heavy metals Fe, Zn and Cd has been reported in some localized areas. Eutrophication is the most significant pollution in southern Vietnam due to wastewater input from domestic activities, agriculture and aquaculture. Resulting red tides and shellfish poisoning cost brackishwater shrimp farming many thousands of Vietnamese Dong (1USD = 10,000 Dong) in 1996. The most significant pollution derived from the rapid economic growth in the Red River basin would be an increased nitrogen loading (Tri, this report).

Pearl River
The most pronounced state changes in the receiving marine environments of the Pearl River are eutrophication, algal blooms and contamination of water resources. Input of pollutants leads to eutrophication, algal blooms, oxygen depletion and contamination of water. Eutrophication is severe in the lower reaches of the river and estuarine zone due to the prolonged water residence time. The replacement of natural wetlands, which was a natural sequestering site for nutrients, with man-made grow-out ponds that are highly enriched with fertilizers, serve as sources of dissolved and particulate nutrients. One negative effect of eutrophication is red tides, which occur frequently in the western part of Hong Kong. The dinoflagellate bloom of *Gymnodinium milkimotoi* in 1998 resulted in massive fish kill and the loss of stocks worth $US80 million. Other harmful algal bloom (HABs) species are *Prorocentrum minimum*, *P. micans*, *Alexandrium tamarense*, *A. catenella* and *Scrippsiella trochoidea* (Wong and Wong, this report).

The Pearl River carries annually ca. $55x10^3$ tonnes of oil to the waters of South China Sea with a higher loading in summer and lower loading in spring. Oil compounds in seawater mainly come from land, vehicle spilling on highways and ships. Persistent organic pollutants (POPs) have contaminated both the river water and sediment of the Pearl River Delta. They are hydrophobic and can bio-magnified through the food web up to humans. The levels of DDTs and PCBs in whale blubber were 33 and 2 mg kg^{-1} in the South China Sea and 48 and 35 mg kg^{-1} in dolphin blubber in the Pearl River delta, respecively. In human breast milk in Hong Kong and Guangzhou, γ-HCH (0.95 mg g fat^{-1}) and p,p'-DDT (2.68 mg g fat^{-1}) were 2-10 times higher than in Europe and Canada (Wong and Wong this report).

Area 2: East China Sea, Yellow Sea and Bohai Sea

Fluxes of nutrients in river and atmosphere
Chinese rivers and probably Korean rivers have high concentrations of nutrients compared to large and less disturbed rivers because they are derived from agricultural and domestic sources over their watersheds. The elevated seawards nutrient element transport can be in part attributed to the intense agricultural and domestic activities (Zhang 1996). The annual production and consumption of chemical fertilizers has increased significantly in China since the 1980s, although time-series data on riverine nutrient end-members are still too limited to substantiate the claim that fertilizer use in the watersheds is directly linked to the observed high nutrient concentrations in rivers. Zhang (1996) reported that concentration of nitrate has increased by a factor of 4-5 times from 1963 (15 μM) to 1980 (65 μM).

Comparison of atmospheric input with riverine transport to East Asian seas reveals that as a preliminary estimate, atmospheric deposition is a major pathway for nutrient elements to this region, which may be equal to or even more important than the rivers, depending upon the elements and rainfall and surface freshwater discharges in combination. In particular, concentrations of nutrients in rain/snow samples are high, e.g., 1.4-182.7 μmol kg^{-1} for NO_3^-, 6.5-250 μmol kg^{-1} of NH_4^+, 0.06-8.56 μmol kg^{-1} for $PO4_3^-$ in the Yellow Sea (Zhang and Liu 1994). The atmospheric regime in the Yellow Sea can be related to (1) the extensive spread of cultivation in North China, (2) rapid economic development and population increases in the coastal areas of the contiguous land masses of China and Korea, and (3) long-distance transport of both natural sediments (soil-dust) and pollutants (e.g., combustion of fossil fuel) from the continent, a significant contribution to the atmospheric deposition over the region because East Asian seas are under the influence of westerly winds of the Northern Hemisphere. Chinese emission of SO_2 has increased ca. 5% annually over the last 30 years, while the emission ratio of SO_2/NO_2 has gradually decreased due to the shift to cleaner fuel in recent decades, so that the marine impact of industrial emissions will become relatively more significant in the coming decades.

Changes in nutrient fluxes and productivity

The alteration of ratios among nitrogen, phosphorus and silicon in the coastal ocean has changed due to human impacts in the watershed. In the past, nitrogen and phosphorus were discharged through the sewers, but nitrogen became more enriched in the sewage after the 1970s when phosphorus-free detergents became available in both China and Korea. Phosphorus is more resistant than nitrogen to weathering. In the phytoplankton-based system (i.e., autotrophic), diatoms are the preferred phytoplankton species leading to more profitable commercial resources. Diatoms have silicon skeletons, and hence populations dominated by diatoms need a supply of silicon if they are to produce new cells. Diatoms use silicate more rapidly than nitrate and silicate is a potentially limiting factor in the sea area of this region. Silicon appears to be regenerated much more slowly than nitrogen in equatorial Pacific oceanic waters (Dugdale and Wilkerson 1998). The available data suggest that silicon limitation over nitrogen uptake should be closely investigated. Silicate depletion relative to nitrogen nutrients has been observed in many coastal waters in Korea (Pae and Yoo 1991). Therefore, the major phytoplankton species have shifted from diatoms to flagellates, and harmful algal blooms (HABs) have occurred more frequently in recent decades. Large water bodies in East Asian marginal seas have shown a similar phenomenon of relative silicate depletion, notably the Bohai. In the Bohai, both concentration and the elemental ratios among nutrients have changed dramatically during the last 20 years, probably due to the decrease of Huanghe sediment and water discharges. The increase of nitrogen and decrease of phosphate and silicate has led to an increase of the N/P ratio and a decrease of the Si/N ratio. The previous nitrogen limitation has switched to a phosphate and silica-limiting environment. This in turn limits diatom growth and promotes the development of pyrrophyta HABs in the Bohai (Yu *et al.* 1999).

The amount of Chinese national waste drainage entering the seas exceeded 6.5×10^6 t yr^{-1} in the 1990s, of which 80-90% was carried by rivers (Xu 1992, cited in Zhang *et al.* 1997). Economic losses related to waste drainage and pollution of the marine environment reached several billion yuans of RMB ($1.0 U.S. = 8.25 yuans of RMB). Hazards and catastrophic events, such as harmful algal blooms and reduced production of marine culture, were more serious in the 1990s compared with 10-20 years ago (Zhang *et al.* 1997). The Korean coast also receives as much as 0.87×10^9 m^3 of wastewater annually, and suffers from frequent HABs. The frequency of red tide occurrence has increased since 1970s. The damage of HABs is estimated as much as 79.78×10^9 Wons ($1.0 U.S. = 1100 Wons) in 1995. Most damage was done to the cage fish culture and hanged oyster culture (Ministry of Environment 1997).

Comprehensive understanding of the nature of primary productivity in the sea is essential for the sound management of marine resources. However, the controlling factors for primary productivity have rarely been understood in the East Asian marginal seas. Recently major field measurements on new and regenerated primary production were undertaken for the Yellow Sea (Yang *et al.* 1999b). Regenerated primary production makes up more than 60% of the primary production in the Yellow Sea. The overall dominance of ammonium utilization by phytoplankton appears to have resulted from the consistent preference for ammonium and the presence of a higher affinity/higher capacity uptake system for ammonium than nitrate. In the coastal region inside of the tidal front, both new and regenerated production are high; however, in the much wider Yellow Sea proper, both new and regenerated production are low (Yang *et al.* 1999b). The Yellow Sea proper is always in an oligotrophic state due to the lack of nutrients during the year except in winter (Chung *et al.* 1999). Therefore, the Yellow Sea is very fragile/sensitive to external forcing, wind and atmospheric inputs. The effects of storms to mix the water column, to provide new nutrients into the upper euphotic layer and hence to lead to phytoplankton blooms has not been addressed in the Yellow Sea, but three and four days of a cycle of atmospheric pressure change is expected to induce a phytoplankton bloom in the Yellow Sea proper as modelled by Bissett *et al.* (1994) in other oligotrophic oceans. Significant amounts of nitrate in aerosol, Yellow Dust storm events and concurrent HABs in the Yellow Sea proper have been reported by Zhang and Liu (1994) and Zhang (1994).

Coastal morphology changes arising from sedimentation dynamics off the mouth of the Huanghe (Yellow River)

The rate of sediment suppply from the Huanghe (Yellow River) into the Yellow and Bohai seas has changed significantly due to human intervention throughout Chinese civilization. Yang *et al.* (1998) summarized detailed historical records, which show that the Huanghe was about 10% of its present size before 800 B.C. From 800 B.C., sediment discharge increased dramatically to 80% of the present due to mass cultivation in the loess plateau which has been the main sediment source area for the Huanghe. The silty loess plateau extensively eroded into the Huanghe until 200 A.D. After nomadic South Huns arrived and cultivated the loess plateau in 200 A.D., the rate of sediment discharge decreased again. However around 600 A.D. the rate of sediment discharge increased again due to the cultivation of loess plateau by immigrants fleeing from the wars in central China, and it has gradually reached the present level of sediment load. Before 1126 A.D. the Huanghe debouched into the Bohai and sediment from the Huanghe was transported to the Yellow Sea through the Bohai Strait. In 1126 AD, the southern side of the river embankment near Kaifeng was removed to prevent the advance of cavalry troops of the Jin minority, and the river course shifted to the south of the Shandong Peninsula. The Huanghe then discharged directly into the Yellow Sea and formed the river delta off the coast of Jiangsu Province. In 1855, the river mouth shifted again to the north and sediment supply to the Yellow Sea greatly diminished again. Currently, the Huanghe no longer flows into the sea for a large portion of the year due to the increased water consumption by industry, agriculture and a growing population during the last 20 to 30 years. The Huanghe delta's shift from rapid accretion to coastal erosion is a dramatic shift in the development of coastal morphology (McLaughlin, this report).

Changes in sediment accumulation on the Yellow Sea bottom due to changes of the river course and dam constructions of the Huanghe

Sediment discharge from rivers to the sea has decreased due to the construction of dams along the river courses and to increased water demand in the drainage basins on the East Asian continent. These changes are reflected in coastal sedimentation rates. The use of dated cores makes it possible to reconstruct historical changes in sediment delivery. For example, the Yellow Sea has undergone substantial changes in sediment accumulation on the sea floor. The ^{210}Pb-derived sediment accumulation rates are 28 to 72 mg cm^{-2} yr^{-1} (0.02 to 0.03 cm yr^{-1}) in the distal bottomset deposits of the subaqueous abandoned Huanghe delta (35°51.30'N 124°32.80'E) and are 772 mg $cm^{-2}yr^{-1}$ (0.57 cm yr^{-1}) off the Jiangsu coast (33°30.00'N 122°30.00'E) (Hong, unpublished data). Alexander *et al.* (1991) found that apparent accumulation rates in the Central Yellow Sea (distal bottomset deposits of subaqueous abandoned Huanghe delta) increase from 0.03 cm yr^{-1} (20 mg cm^{-2} yr^{-1}) to 0.27 cm yr^{-1} (220 mg cm^{-2} yr^{-1}) from east to west across the Central Yellow Sea. High sedimentation rates were observed off the Jiangsu coast (0.4 cm yr^{-1}, estimated from the depth distribution of excess ^{210}Pb from Nagaya and Nakamura 1992). Much higher sedimentation rates off the Yangtze River (5.4 cm yr^{-1}) were found by DeMaster *et al.* (1985). Excess ^{210}Pb down core distributions suggest that the surface of the mud deposit is contemporaneous. Sediments are transported from north to south-east along the Chinese coast, especially during winter storm periods (Milliman *et al.* 1985). In the eastern part of the Central Yellow Sea, an abrupt slowdown of sedimentation rates appears to have occurred around 60 to 80 years ago, declining from 168 mg cm^{-2} yr^{-1} (0.11 cm yr^{-1}) to 59 mg cm^{-2} yr^{-1}(0.04 cm yr^{-1}) and 248 mg cm^{-2} yr^{-1} (0.34 cm yr^{-1}) to 28 mg cm^{-2} yr^{-1} (0.04 cm yr^{-1}) at stations located in the central part of the Yellow Sea (the former was at 35°51.30'N 124°32.80'E and the latter was at 35°41.00'N 124°37.00'E). The Huanghe mouth shifted from south of the Sandong Peninsula (Yellow Sea) to north of the peninsula (Bohai Sea) in 1855. The Huanghe again drained into the Yellow Sea for a short period around World War 2 (1938-1947). Although ^{210}Pb derived sediment age has a large uncertainty due to slow sediment accumulation, the recent decrease of sediment accumulation rate corresponds to the decrease of sediment supply from the old Huanghe delta and the Bohai. The annual sediment discharge of the Huanghe decreased from ca. 1.1x 10^{9} t yr^{-1} in 1950 to ca. 0.7x10^{9} t yr^{-1} after 1970 due to soil conservation and dams construction (Yang *et al.* 1998). More than 90% of the Huanghe sediment load is deposited in the lower reaches of the river and within the estuarine area. Therefore the actual sediment flux to the Yellow Sea is very limited and it may take place via a nepheloid layer across the Bohai Strait which would transport ca. 6x10^{6} t yr^{-1}, i.e. less than 1% of the Huanghe sediment discharge (Martin *et al.* 1993). Sediment supply from the Korean Peninsula to the central part of the Yellow Sea is not likely to be significant (Chough and Kim 1981; Alexander *et al.* 1991). The impact of change in sediment accumulation rate on the benthic biota is not available for the Yellow Sea.

Changes in salinity in the surface water due to runoff changes

Due to the large freshwater discharge from rivers into the East Asian marginal seas, the seas have been subjected to the significant lowering of salinity (more than 1 psu) every summer depending upon the magnitude of precipitation. In the area off Cheju Island, salinity dropped as much as 6 psu below the normal value in early August 1998, causing a mass mortality of oyster and abalone in the aquaculture area (Joongang Daily, 6 August 1998). Construction of barrages across lower river courses also significantly modifies the salinity regime near the river mouths. A few examples are given here.

<u>*Keum River barrage*</u>
Freshwater discharge was as much as 156 m^3 s^{-1} before the river barrage was built in 1994. During the summer heavy rainfall, the riverine freshwater propagated as far as 10 km to the west and as far as 50 km to the north (Seung *et al.* 1990). Since barrage construction, the freshwater is discharged from the barrage only during the normal flow period. However, during heavy rains the water gate is opened in order to prevent flooding in the watershed. For example, 1.5×10^9 m^3 of water was discharged into the Yellow Sea during the period 1-12 July 1997. As result, a 5-6 m thick low-salinity (less than 30 psu) plume was distributed over the large area between the Keum River and Ochong Island, up to 100 km off the river mouth. During heavy rain periods since barrage construction, the instantaneous freshwater discharge rate is higher than before the barrage construction. Thus, vertical mixing due to tide and wind is more suppressed, and vertical distribution of water density is more pronounced than before the barrage construction. Consequently, the river plume spreads in a much wider area and more rapidly (Choi *et al.* 1999). The ecological consequences of lowering salinity in the region have not been studied yet.

<u>*Changjiang effluent plume*</u>
The Changjiang effluent plume significantly modifies the salinity field in the East Asian marginal seas. In the Yellow Sea, CTD data obtained in recent decades reveal a well-posed annual cycle for distribution of low salinity water in summer. There are five major water masses in the Yellow Sea: Yellow Sea Warm Current Water (YSWCW), Yellow Sea Bottom Cold Water (YSBCW), Korea Coastal Water (KCW), China Coastal Water (CCW) and Changjiang Diluted Water (CDW). In summer, a low salinity core is formed in the surface 20 m depth in the southern Yellow Sea since the trapped CCW and CDW are piled up in the west of Cheju Island. This low-salinity core water drifts eastwards as a single body to adjust the basin-scale pressure fields (Lee *et al.* 1999). A water residence time of 5.6 years in the Yellow Sea has been derived using salinity, river discharge rate, precipitation and evaporation data over the Yellow Sea, indicating that freshwater input from the Changjiang dominates the budgeting of water in the Yellow Sea (Lee *et al.* 1999). The uncertainty is largely due to three major factors: the amount of discharge from the Changjiang to the Yellow Sea, salinity difference between the Yellow Sea and the East China Sea, and the problem of a single-box model for the riverine input-dominated system. Among the three factors, the uncertainty increases if the Changjiang input into the Yellow Sea is less than 20% of the total riverine discharge rate. The Changjiang input into the Yellow Sea is estimated to be 14.1% ($130 \times 10^9 m^3$) of the annual freshwater discharge, assuming average surface mixed layer is 10 m and using monthly salinity data (Liu *et al.* in review). This amount is by far the largest freshwater source in the Yellow Sea, Cheju-Korea Straits region and the Uleung Basin in the Sea of Japan (Hong *et al.* this report).

Nutrient fluxes via ocean currents

The fluxes and distribution of nutrients are derived by strong seasonal variations of wind and precipitation since the region is under the influence of North-east Asian Monsoon. The Cheju and Tsushima currents are two major material and nutrient streams in the East Asian marginal seas. The Cheju Current carries water from the Yellow Sea and the East China Sea to the Sea of Japan via the Cheju Strait. The Tsushima Current carries Kuroshio water to the Sea of Japan via the Korea Strait. In the wet monsoon period every year, a significant amount of freshwater, nutrients and other land-derived material from the Chinese continent discharges via the Changjiang into the western part of Cheju Island. Korean rivers discharge their material into the western and southern coastal waters. These are later entrained by the Cheju Current (0.37 to 0.58 Sverdrup (sv) with maximum speed of 15 to 20 cm s^{-1}) and further moved to the Cheju-Korea Straits (Suk *et al.* 1996). Thus the Cheju Current forms a strong nutrient pathway in the East Asian marginal seas (Chung *et al.* 2000), which eventually feeds the Sea of Japan. Water volume-specific nutrient fluxes through the Cheju Strait are a 2-3 times higher than those of the Tsushima Current between Cheu and Kyushu islands, and comparable to that of the Kuroshio off Taiwan (Hong 1999).

The amount of annual precipitation has increased in recent decades in the southern coast of Korea and Cheju Island. Time-series of monthly mean precipitation data are available for Pusan and Mokpo since 1910, for Cheju since the late 1920s, for Yosu since the late 1940s and for Sogipo since 1960 (Hong 1999). The inter-annual variability was observed with quasi-period of 2 to 7 years relative to the El Nino period and a longer time-scale (interdecadal) fluctuation, especially in Cheju. The linear increasing trend of precipitation is about +7 mm/10 years in Pusan and Mokpo, +16 mm/10 years in Cheju, and much higher in Yosu (+40 mm/10 years) and in Sogipo (+80 mm/10 years) where the total precipitation is the highest in Korea. This increase in precipitation has led to an increased erosion rate of the land surface and hence an increase the material export from the land to the sea.

The hydrographic records of greater China go back to the mid-late 19th Century. For example, the measurement of water discharge of the Changjiang can be traced back to 1865, and the annual maximal water discharge at lower reaches show a rising trend (Zong and Chen 2000). Human activities over the drainage basin have considerably reduced water quality and the flood storage and drainage capacities of landscapes, notably by deforestation and pollution. Probably due to the increased influx of nutrients, silicate has a major impact on the chemistry of the Sea of Japan. Numerous examples reveal that the oceanic environment is changing due to either natural or man-made variations in climate and river runoff (Chen *et al.* 2000).

Area 3: Sea of Japan, Okhotsk Sea and Bering Sea

The northern sub-region of East Asia is sparsely populated and relatively underdeveloped, therefore the coastal issues arising from change or human activities in the catchment basins are not prominent at present. However, due to planned increases in industrial development, such as the Tumen River Area Development Program (TRADP), potential coastal issues are not insignificant.

The Sea of Japan coast of East Asia lacks major rivers, so coastal issues, state changes, critical loads and ranking arise from activities in the catchment basins. The influence of Tumen River discharge is limited to within 8-16 km from the mouth and to a depth of less than 10 m, even during the typhoon period (Tkalin and Shapovalov 1991). Minor contamination of heavy metals, petroleum hydrocarbons and chlorinated hydrocarbons was noted in the coastal waters north of the Tumen River (Belan 1999; Tkalin 1999). The Razdolnaya River has been regulated for agricultural purposes since the 1980s. Large cities, such as Vladivostok and Ussurijisk, and heavy industries are more concentrated in the drainage basin of Amursky Bay. There is no major industry other than the naval shipyard of Bolshoi Kamen in Ussurisky Bay. Major discharges of municipal and industrial waste are into Amursky Bay (Tkalin *et al.* 1993; Hong *et al.* 1996). Concentrations of phenols, anionic detergents and aromatic hydrocarbons are higher in the Sea of Japan proper than in the Yellow, East China or Philippine seas (Tkalin 1991). The coastal waters off the Rudnaya River in the middle of Sikote-Aline coast are contaminated with the heavy metals Pb, Cd, Cu and Zn due to mining activities (drainage waters, wastes and tailings) (Shulkin 1998).

The Sea of Okhotsk is the one of the southernmost ice-covered oceans in the Northern Hemisphere. The inflow of freshwater from the Amur River suppresses the deep convection and promotes freezing (Ogi *et al.* 2000). Assuming that the runoff water spreads out uniformly within the immediate area off the mouth of the river, the annual accumulation of freshwater will range from 2.6 to 5.0m yr^{-1}. Therefore, increased human activities in the river basin will contaminate the Sea of Okhotsk. During the last decade, an economic crisis led to a three- to four-fold increase in agricultural production in the Amur River region.

Poor farming practices such as burning straw and extensive use of herbicides and pesticides have caused long-term damage to soils, wildlife, human health and the economy.

The Bering Sea receives freshwater from the Anadyr River. Although the river basin is largely pristine, high As and Sb levels are attributed to the local mining activities.

Coastal issues, state changes, critical loads and ranking in East Asia

Catchment basin activities have considerable influence on the environmental states of many East Asian coastal areas. Specific examples summarized in Table 2.6 address key issues and scales rather than expressing the entire dimension of the continent's land-based problems occurring at the land-sea interface. A tentative critical load approach is given for the catchments highlighted during the workshops. Critical loads represent quantitative estimates of ecosystem sensitivity to a given impact and may be compared to the present-day state of the ecosystems regarding a given parameter and/or pressure.

Coastal impacts and issues on the coastal zone of East Asia were characterized and ranked according to their degree of importance, based on a quantitative or qualitative evaluation of the present-day distance to the critical threshold of a given parameter for system functioning.

Major important coastal issues in East Asia are erosion and coastal morphology changes, eutrophication and harmful algal blooms, pollution and biodiversity loss and/or decreasing biological productivity, although other issues may be even more important at the site-specific level (see individual sub-regional tables in Appendix II). These issues have already caused measurable impacts on the sub-continent's coastal zone resulting in varying degrees of displacement from baseline background state in many ecosystems.

Erosion

The extreme climate conditions of the East Asian monsoon and the damming of rivers has significantly distorted the erosion-accretion equilibrium of large stretches of the East Asian coastline. These effects are most apparent where water resources are abundant seasonally in Vietnam and South China, and where water resources are scarce due to population growth in the catchment areas, in coastal metropolitan areas or in arid climates. Examples can be found along the Vietnamese coast (Than *et al.,* this report) and in the old Huanghe delta and current Huanghe delta. Diversion of water resources in the upper reaches of the rivers and the Great Western Development are of particular importance in the Yangtze and Yellow rivers (Yang *et al.,* this report; Saito *et al.,* this report). In the tropical island of Taiwan, the sediment yield in river catchments ranks as one of the top ten rivers in the world due to the torrential rain brought by typhoons and active tectonic uplifting of the island (Chen, this report).

Eutrophication and harmful algal blooms (HABs)

Nutrient-rich agriculture and domestic waste released to the coast is raising special concerns regarding trophic and toxicological aspects of coastal waters. Rivers in Vietnam and South China are experiencing very serious HABs resulting in fish kills, especially of aquaculture (Than *et al.*, this report). Red tides are frequent in the Bohai Sea off the Liao and Hai rivers (Yu *et al.*, 1999) and coastal areas of Taiwan (Chen, this report), Korean Peninsula (Hong *et al.*, this report) and Japan.

Pollution

The most common contaminants in the coastal zone of East Asia are oil, PAHs and pesticides in Vietnam and South China (Area 1), and heavy metals in the central sub-region (Area 2) and northern sub-region (Area 3). Persistent organic pollutants (POPs) and heavy metals, which are taken up by living organisms and subsequently by humans, have been reported. DDT and HCH concentrations in oysters in the western waters of Hong Kong SAR and in human breast milk were 2-10 times higher than those of European and Canada (Wong, this report). Oil pollution from offshore oil exploitation resulted in habitat loss in the coastal waters off Sakhalin Island (see individual sub-regional tables in Appendix II).

Most pollutant inputs are from agriculture and industrialisation along river catchments in Vietnam and South China (Area 1) and in the central sub-region (Area 2) and from terrestrial and offshore mining including oil exploration in the northern sub-region (Area 3). Atmospheric deposition of pollutants is very significant in northern East Asia. The Yellow Dust storms of early spring form one of the most salient meteorological features of the region. Unlike the contaminants introduced into the coastal ocean and usually confined to the immediate area of the river mouth and its estuary, atmospheric input is exerted over the entire marginal seas, so that the spreading of contaminants is more extensive via the atmosphere than via rivers.

Biodiversity loss and decreasing biological productivity
Due to the increased demand for food, energy, water and space for sustaining a larger population, there is acute and intense competition between man and the environment in East Asia. Exploitation of living resources has resulted in habitat loss of mangroves, coral reefs and seagrass beds, and led to decreases in numbers of species and wetlands in Vietnam and South China. Fishery resources may decline with further contamination, overfishing or reduction of freshwater outflow of the Yangtze River due to the diversion of its water course in the East China Sea. The ecosystem in the Bohai has been changed from diatom-based to flagellate-based due to the N/P/Si ratios of river water caused by the cutoff of the Huanghe discharge and, therefore, fisheries have become less sustainable (Yu *et al.* 1999). Overfishing and over-crowding of prawn cultivation affects about 1000 km^2 offshore of the Hai and Liao rivers in the Bohai. The coastal fisheries in the west of Taiwan have already been cut by half due to contamination and overfishing (Chen, this report).

Coastal flooding
Floods occur almost every year in Vietnamese small rivers and in the Mekong River. There is little flooding in the Red River. However, once there is a flood, it is very dangerous for residents in low-lying areas due to the dyke systems. The recurrent period of big floods is about 200 years. Floods also occur almost every year in South China and Hong Kong with the record high in 1915. The Amur River and the small Razdolnya and Rudnaya rivers in the Russian Federation also suffer occasional floods leading to increases in sediment transport and water levels in the catchment basin (see individual sub-regional tables in the Appendix II).

Saltwater intrusion
In Vietnam and South China, saltwater intrusion is a regional phenomenon, because of the wide flat areas of Mekong, Red and Pearl River deltas. Rice cultivation is affected when salinity exceeds 0.5 psu, and drinking water becomes salty in Macao and in Vietnam. Spawning of prawns and fishes is also affected by salinity increase (see individual sub-regional tables in Appendix II).

Sea-level rise and land subsidence
In the central sub-region of China, inundation of lowlands of the delta by storm surges and high tides in addition to possible future sea-level rise is a regional concern. Land subsidence in Shanghai and western Taiwan is a result of groundwater pumping. In the Japanese islands, most sandy beaches are expected to be lost within the next 100 years due to sea-level rise (see individual sub-regional tables in Appendix II).

Table 2.6 Major coastal impacts/issues and critical thresholds along the East Asian coast.
Overview and qualitative ranking of impacts: 10 = maximum; 0 = none

Coastal Impact/ Issue	Local site/Region (contributing river basins)	Critical Threshold (for system functioning)	Distance to Critical Threshold (qualitative or quantitative)	Impact category	References/ Data source
Erosion (coastal geomorphology)	a. Rivers of southern region, Vietnam (Mekong and Red Rivers),and Pearl River of southern China including local and low lying river estuaries and adjacent beaches	a. Estimated 114 $x10^6$ t/year (Red River). Dams and dikes trap sediment.	a. From 3620 km upper coastline,469 km of coastline has been eroded, 100km from Pearl River Delta (PRD) and adjacent areas have been eroded, especially during wet season (May to November).	10	Than *et al.* (this report) Wong and Wong (this report)
	b1. Central China (Yellow River, Yangtze River, and old-Yellow River delta), other smaller rivers (Liao, Hai rivers)	b. 0.35 $x10^9$ t/yr (Yellow River) and 0.47 $x10^9$ t/yr (Yangtze River) 6 $x10^6$t/yr (Hai River), 26.7 x 10^6 t/yr (Luan River) to the Bohai Gulf	b1. Zero. Yellow River has affected the formation of delta (Yangtze River), already some of tidal flat of the old-Yellow River delta has been lost	10 (Yellow River) 10 (Old Yellow River delta) 8 (Yangtze) 3 (Hai)	Yang and Saito* Saito and Yang* Ren *et al.* (1994), Xi *et al.* (1994), Xing* Chen (this report)
	b2. Tropical island Western Taiwan, (Kaoping River, Taiwan)		b2. Already causing collapse of a major bridge on the river and loss of beaches in Kaoshiung City, 1000 km^2 of coastal land is subsiding	8	Saito (this report)
	b3. Japanese island/Rivers		b3. Already most of coasts are artificial.	10	Hong (this report)
	b4. South Korea (west and southern coasts)	b4. Most river mouths are dammed, no sediment input to the sea	b4. Large portion of coasts are artificial, sand beach erosion is common	8	
	c. Northern region (Bering Sea, Sea of Okhotsk, Sea of Japan	c. Not known			

Table 2.6 continued

Eutrophication /Harmful Algal Blooms (HABs)	a. Rivers of Vietnam and southern China (e.g. Pearl)	Very serious, resulting fish kills (HABs toxins). HABs appear and die suddenly, using up oxygen during bacterial decomposition. Worst case in 1998 in China and Hong Kong. HABs in Mekong is not serious. Dinoflagellate bloom Nutrient overload	Fish kill is a good indicator. In the case of mariculture in HK, when there is a fish kills caused by red tides, HK government will verify and compensate.	9	Wong& Wong (this report)
	b1. Yangtze River in Central China		b1. Increased nutrient loads are expected in the future and the system will change.	9	Watanabe*
	b12. Liao and Hai rivers of China	Lack of Si due to the decreased flow of the Yellow River	Red tides occur often	10 and 9, respectively	Xing and Pu (this rep.), Xing*
	b13. Bohai Gulf	Damage to aquaculture	Phytoplankton community shift from diatoms to flagellates	5	Yang* Yu *et al.* (1999)
	b21. Western Taiwan		Most estuaries are already eutrophicated, and HABs cause some human casualties	8	Chen (this report) Chen (this report)
	b22. Eastern Taiwan		Isolated cases of eutrophication	3	Chen (this report)
	b3. Japanese Islands	Violation of N, P. COD standard, occurrence of anoxia in estuaries	Not satisfied in a few enclosed bays	6 3	Watanabe (2001)
	b4. South Korea (west and southern coasts)	Occasional HABs.	Southern coastal bays are already eutrophicated. HABs damage cage fish cultures occasionally.	7	Hong *et al.* (this report)
	c1. Northern subregion (Amur, Tumen, Peter the Great Bay)	Organic matters	Habitat loss	2	This report (for details contact working group members)
	c2. Eastern Korean coast, up to Tumen River estuary		Habitat loss, red tides occasionally	2	

Table 2.6 continued

Pollution*	a. Southern rivers of Mekong, Red, Pearl, Hanjiang and Nandujiang	Oil, PAHs and pesticides pollution is typical in the region from the industries and oil exploration offshore.	Increased concentration of pollutants.	8	Than *et al.* (this report)
			In China 2 standards, 1 for freshwater, 1 for seawater, more than 30 parameters. Type I the best. Most falls in type II. Open sea always Type 1. In terms of POPs and heavy metals, can be reflected by uptake of contaminants in living organisms, e.g., oysters in western waters of HK, human breast milk, DDT and HCH, 2-10 times higher than in Europe or Canada		Wong& Wong (this report)
	b. Central China.				
	b11. Yangtze River	Hg 0.012, Cd 0.85	Heavy Metals: Cr 0.75-57 mg.kg^{-1}	7	Xing*
	b12. Liao River	Metal concentration in river: Pb(17.7-53.4 mg/L);Cd (0.18-0.106 mg/L); Volatile phenol (0.33 mg/L), Petrol materials (85.5-355 mg/L), Pesticide (0.04-0.125 mg/L)	Pb 0,7-141 mg.kg^{-1} Cd 4-231 μg.kg^{-1} Cu 109 μmg.kg^{-1} Pesticides: 10-250 ng DDT /L Hydrocarbons (Petroleum contam.)	7	Xing*
	b13. Hai River	Violation of standards		6	
	b21. Eastern Taiwan	Exceeding standards	slightly polluted	2	Chen (this report)
	b22. Western Taiwan		heavily polluted	8	Chen (this report)
	b3. Japanese coastal zone	Violation of standards	no violation found	1	Watanabe*

Table 2.6 continued

	b4. Northern subregion	Heavy metals contamination			
	b41. Bering Sea coast		Habitat loss and biota contamination	2-3	Russian papers (1979-1998)
	b42. Small rivers in the Okhotsk Sea, Amur River	Heavy metals	Habitat loss and biota contamination	2	
	B43. Sea of Japan (East Sea) small rivers, Tumen, Amur, Peter the Great Bay	Organic matter Heavy metals and organic matter pollution	Habitat loss	1 (metals), 2-3 (organic matter)	
	B44. Sakhalin Island	Oil pollution	Habitat loss	1	
Biodiversity loss and/or decreasing biological productivity	a. Rivers in Vietnam and southern Chian	Caused by exploitation of living resources, habitat loss and different factors. Threshold indicator- mangrove, coral reefs, seagrass destruction, sedimentation. However, it is difficult to pinpoint the effects of food chain and food web.	The number of species decreased (birds, aquatic organisms) SE Asia project on seagrass study showed 10 to 20 species loss Some data on mangrove and coral loss Destroy of wetland in HK due to urban expansion and land reclamation	7-9	Wong & Wong (this report)
	b1. Central China				
	b11. East China Sea	Caused by limited Si supply due to the cutoff the riverwater discharge	Not sustainable, may decline with further contamination, overfishing or reduction of freshwater outflow of the Yangtze River.	8	Chen (this report)
	b12. Bohai Gulf		Not sustainable, may decline with further contamination, overfishing or reduction of freshwater outflow of the Yellow River	5	Yu *et al.* (1999)
	b13.Hai River		Overfishing	10	Xing (this report)
	b14. Liao River		Prawn cultivation zone reaches to 1300-1400km, affects the sea about several 10^3 km^2, P is overloaded.	10	Xing (this report)
	b21. East Taiwan		Little effect	1	Chen (this report)
	b22. West Taiwan		Already cut by half due to contamination and overfishing	10	Chen (this report)
	Northern Region		No information		

Table 2.6 continued

Coastal flooding	a. Vietnam and southern China (Mekong, Red and Pearl rivers)	Floods occur almost every year in Vietnamese small rivers and Mekong River. Little flood in Red River. However, once there is a flood, it is very dangerous to low land area due to dyke systems leach to towns.	Residents in south and center of Vietnam are suffering from floods.	9	Than *et al.* (this report) Wong & Wong (this report)
		Floods occur almost every year with the record high in 1915 in southern China. Hong Kong is having big floods as well.	The recurrent period of big flood is about 200 years. The cause of flood is not known.		
	c. Northern subregion: Amur River, Razdolnya, Rudnaya, other small rivers	Increasing sediment transport and water level	large	2-3	
Saltwater intrusion	a. Vietnam and southern China	- Rice cultivation is affected when salinity exceeding 0.5 ppt - Drinking water became salty at Makao and in Vietnam - Spawning of prawns and fishes is affected	More significant in major rivers, because of flat gradient (Mekong, Red, Pearl). Regional phenomenon, not local	7	Wong& Wong (this report)
Sea-level rise (and land subsidence)	b1. Central China: b11. Yangtze River		Inundation of lowlands of the delta by storm surges and high tides in addition to the future sea-level rise is estimated. Subsidence in Shanghai by ground water pumping.	4	Saito*
	b12 Hai River		Caused by groundwater over-pumping.	8	Xing*
	b21 Eastern Taiwan		Not a problem in the foreseeable future.	1	Chen (this report)
	b22 Western Taiwan		1000 km² of coastal land is subsiding as a result of groundwater pumping.	8	Chen (this report)
	b3. Japanese Islands		Loss of most sand beaches is expected within next 100 years.	4	Saito*

* - *Further information available from workshop participants*

2.5. Driver-Pressures-State Change relationships

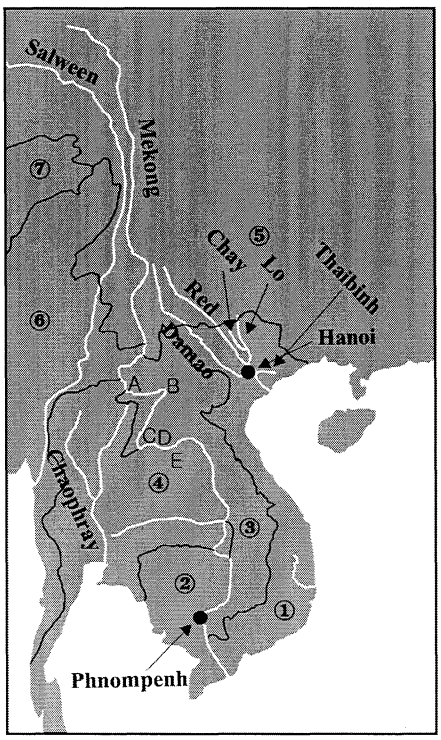
Area 1: South China Sea

The Mekong system: Damming

The Mekong River descends from the Tsinghai Province of the Tibetan plateau in China (Tibet Autonomous Region and Yunnan Province), flows across Myanmar, Laos, Thailand, Cambodia and finally enters Vietnam. There are three sections of the Mekong River: high, middle, and low. The low section extends from Phnom Penh to the South China Sea, a distance of 340 km with a slope of about 2.5 m km^{-1}. Entering Vietnam, the Mekong River splits into an eastern branch, called the Mekong River, and a western branch, the Bassac River; the Mekong flows into the South China Sea by nine distributaries. The 50 million residents and countless river and floodplain biota of the basin depend on the Mekong's annual flood-drought cycle.

The Mekong River represents a last chance of sorts - the last chance to tap a large, relatively pristine river basin's potential to supply energy and water without destroying its environmental integrity. The Mekong River is perhaps the world's least exploited major waterway in terms of dams and water diversions. However, the Mekong's watershed includes six of South East Asia's nations - Cambodia, China, Lao PDR, Myanmar, Thailand and Vietnam. All these governments are eager to promote economic development using the Mekong's water resources (Mekong River Commission, http://www.mrmekong.org). Currently, there are only two dams, one of 500 MW of installed capacity on the lower Mekong and one of 1500 MW on the Chinese section of the river (http://www.un.org.kh/fao/pdfs/section2/chapterx1/11.pdf; Chapman and He Daming, http://www.anu.edu.au/asianstudies/mekong/dams.html).

Planned water resources developments (nine main "run-of-river" hydropower and over 50 tributary dams) have been proposed by the Mekong Secretariat and the governments of Thailand, China, Laos and Vietnam to supply water and power to the region's growing economies. The proposed nine sites are Pak Beng, Luang Prabang, Sayaburi, Pak Lay, Chiang Khan in LAO PDR, Pamong "A" and Ban Koum on the border of Lao PDR and Thailand, and Don Shaong and Sambor in Cambodia (Mekong Secretariat 1994, http://www.usyd.edu.au/su/geography/hirsch/6/6.htm). If these plans are carried out, the relatively undisturbed Mekong River system will be profoundly altered (Figure 2.6).



① Vietnam
② Cambodia
③ Laos
④ Thailand
⑤ China
⑥ Myanmar
⑦ India

A Luang Prabang
B Pak Beng
C Pak Lay
D Chiang Khan
E Pamong

Figure 2.6. Detailed map of the South China Sea and catchments.

The fish caught in the Mekong are the source of 40-60% of the animal protein consumed by the population of the lower basin, and fish sustain an even higher percentage of people in much of Cambodia. The 900,000 tonnes of fish harvested annually and the Mekong's extraordinary fish species richness are threatened by dams which interfere with spawning cycles by preventing fish migrations. Dams also reduce the seasonal floods that sustain fish spawning and nursery grounds in the wetlands upstream and in the delta region. The flood cycle, linked to the monsoon rains, is a critical factor in the life cycle of many of the area's aquatic species. Even slight changes in peak flood flow could threaten the region's fish production and food security. Impacts observed near dams already constructed on Mekong tributaries illustrate the area's vulnerability. Altering the annual flood cycle, reducing the silt load of the water or diverting the Mekong's flow could also have serious impacts on agriculture in the Mekong delta. Flood waters deposit 1-3 cm of fertile silt each year on the lowland flood plains in Vietnam and Cambodia, sustaining these intensively farmed areas. In addition, river flow during the dry season is important for controlling salinity penetration into interior areas from the coast. According to the Vietnam Water Resources Sector Review, seawater penetrates up to 70 km inland during the dry season. If present trends in water abstraction in the delta continue, the area affected by salinity could increase from 1.7 to 2.2 Mha. Increased salinity was cited as the primary cause of rice yield declines of 50-90 percent in Tra Vinh province over the last 30 years (Water Resources Sector Review 1996).

The dangers that dams could pose to the biodiversity of the Mekong must also be considered in the context of the environmental degradation that the region has already suffered. A combination of deforestation, increasing conversion to intensive, chemical-dependent agriculture, continued population growth and mangrove clearance for shrimp aquaculture in the delta region has compromised the basin's environmental health. Vietnam, for example, has already lost approximately 85-90% of its forest cover, largely because of decades of war and reconstruction. In Thailand, perhaps 55-65% of forest has been cleared for agriculture and tree plantations. The Mekong River Commission (MRC) was established to minimize the conflicts inherent in managing a river that crosses many international borders, but its efforts at regional coordination have been largely unsuccessful (Tsering (undated); http://www.tibetjustice.org/reports/mekong.pdf). Despite the current imbalance of power among the riparian countries and the potential for conflict, the benefits of a regional approach are compelling. A basin-wide approach to water mangement would also offer clear environmental advantages. It would force the riparian countries to examine how dams on the upper reaches of the river would affect flow conditions downstream. Currently, the upstream countries can pursue water withdrawals and hydropower production while ignoring repercussions such as saltwater intrusion, decreased catches for subsistence fishing and soil depletion further downstream.

Red River

As much as 0.66 to 0.82×10^6 m^3 d^{-1} of wastewater is produced in the Ha Noi/Viet Tri/Hai Pong industrial area in the north and 34×10^6 m^3 d^{-1} in Ho Chi Minh City in the south. The Red River discharges 0.025×0^6 tonnes of phosphate and 0.035×10^6 tonnes of nitrate into the sea.

Damming has had an important impact on sediment supply by the Red River. The Hoa Binh Dam (storage capacity of 9.5×10^9 m^3) was constructed in 1987 on the Da River, a tributary of the Red River. It trapped 48×10^6 tonnes of sediment (41% of the total transported by the Red River). A larger Son La dam is planned for the upper Hoa Binh River.

Pearl River

Major drivers in the catchment and delta of the Pearl River are population growth, industrialization and urbanization. Although the natural rate of population increase is not high, immigration into the region contributes significantly to the overall population growth, which increased from 9.62×10^6 in 1982 to 21.2×10^6 in 1996. Industrialization has been rapid since 1978 with a substantial decrease in agriculture and a substantial increase in services. Agriculture has shrunk from 26% in 1980 to 9% in 1993, while services increased from 29% in 1980 to 40% in 1993. The provincial income grew at an annual average of 14.2% and established export-led industrialization. Although industrial production was originally confined to a few special economic zones (SEZs), the dispersal of industry from urban centers to satellite towns and rural areas has proceeded at a rapid rate within the delta. Some small and medium investors moved from Hong Kong SAR to the region for the abundant labour and land resources.

Urbanization has proceeded rapidly at the expense of arable land. Some 20% of the arable land has been converted to urban areas. In order to obtain high crop production, about $0.19x10^6$ tonnes of chemical fertilizers ($0.094\ x10^6$ t of N, $0.028\ x10^6$ t of P and $0.033x10^6$ t of K) have been applied in Guandong Province, and excess nutrients are leached out to the river systems. Furthermore, the use of organic wastes such as manure compost has declined, leading to accumulation of organic matters increasing in agricultural runoff. Since mitigation measures are rarely adopted, agricultural surface runoffs contribute to nutrient and organic pollution loadings within the delta and adjacent estuary. It is also believed that polluting industries have taken advantage of the decentralization policy and the failure to implement environmental management within these newly developing regions, resulting in the substantial increase of industrial effluents discharging into the Pearl River directly without treatment. (Wong and Wong, this report).

The key pressures on the system are excess nutrient loads, organic contaminants and oil. Up to $2x10^9$ t of industrial and $0.56x10^9$ t of domestic wastes are generated annually within the region. The wastewater discharged from the major cities of the region consitute ca. 70% of the total discharge of the Pearl River in Guangdong Province. Major pollutants are NO_3^-, MnO_2 and Hg. Nitrate accounts for over 93% of the total dissolved inorganic nitrogen (DIN). The annual input of DIN is $10.2x10^9$ mol yr^{-1} and the levels of DIN in summer and winter are 15 and 24 mmol m^{-3} respectively, with a residence time of 40 days in the estuary. Nitrate concentration is low in summer and autumn and high in winter and spring. The estimated annual input of P is $7.4x10^3$ t with a residence time of 44 days. The levels of DIP in summer and winter are 0.9 and 2.2 mmol m^{-3}, respectively (Wong and Cheung 2000).

Various indices show that organic pollutants have seriously affected the Pearl River. The amount of chloro-pesticides carried by the Pearl River was ca. 863 tonnes, the highest in Chinese rivers. The concentrations of DDT and HCH in marine sediments were high in the eastern part of Guandong Province. The sewage discharged from Guangzhou contains high level of HCHs (0.04-0.38 $\mu g\ l^{-1}$), DDE (0.27 $\mu g\ l^{-1}$) and DDT (0.23 $\mu g\ l^{-1}$). Total concentrations of PAHs in water and sediment in the Pearl River were 1.6 $\mu g\ l^{-1}$ and 477-1137 $\mu g\ kg^{-1}$, exceeding the Dutch Intervention Values (1994) of 0.31 $\mu g\ l^{-1}$ and 1000 $\mu g\ kg^{-1}$. PCBs in the river sediment were 3.4-8.6 $\mu g\ kg^{-1}$, well below the Dutch Intervention Values of 20 $\mu g\ kg^{-1}$ (Wong and Wong, this report).

Area 2: East China Sea, Yellow Sea and Bohai Sea

Socio-economic drivers of change (e.g., C, N, P and sediment fluxes) at the catchment level

About 20% of the world population resides in East Asia. More specifically, 1.23×10^9 people lived in China and 0.07×10^9 persons lived in the Korean Peninsula, in 1998. In recent decades, population increases in China and Korea require more freshwater, more crop production, more industrial/urbanized land and extensive application of fertilizers and pesticides.

China

In China, the total population in 1952 was 5.7×10^8 with the urban population accounting for 12.5%. In 1999, the total population was 1.2×10^9 with a natural growth rate of 8.8 %. The urban population increased to 30.9% of the total population (National Bureau of Statistics 1998-1999). The average population density is 128 persons km^{-2}, although most of the population lives in the eastern part of country, i.e., within 200 km from the coast.

Land use in China covers a wide diversity, including forest, grassland, cultivated and undeveloped lands. Over the total land area of 9.60×10^6 km^2, the cultivated area was 99.4×10^6 ha in 1978, which decreased to 95.0×10^6 ha in 1998. The irrigated area was 45.6×10^6 ha in 1978, and increased to 51.2×10^6 ha in 1997. Energy consumption amounted to 1.42×10^9 t of SEC in 1997, as compared to 96.4×10^6 t in 1957. Of the energy consumption in 1997, coal represents 73.5%, petroleum 18.6%, natural gas 2.2 and hydropower accounts for 5.7% (State Statistical Bureau 1998). In 1980, hydropower production was 58.2×10^9 kWh, which increased to 188×10^9 kWh in 1996.

China is on the eastern side of Euro-Asian sub-continent, under the influence of East Asian monsoons. The climate of China covers a wide range from arid-temperate to humid tropical zones. The annual average temperature ranges from 5°C in the north to 25°C in the south. Rainfall is 100-200 mm yr^{-1} in the north-west inland areas and reaches 1500-2000 mm yr^{-1} on the south-east coasts, with annual rainfall up to 4000 mm yr^{-1} on tropical islands. The humid climate zone in China accounts for 32% of surface area, the arid zone for 31%, with other regions at intermediate positions. Owing to the high altitude of the Qinghai-Tibet Plateau, the geography of China ranges from high mountains in the west to low alluvial plains on the coasts. Large rivers in China rise in the west and north-west and flow east and/or south-east, emptying into the Pacific and Indian oceans. The total surface water volume in China is ca. 3.0×10^{12} m^3, with surface runoff of 2.7×10^{12} m^3 yr^{-1} (State Statistics Bureau 1997, 1998). Rivers in the country have a character of low and high water flow changes in the year; water discharge in the flood season may account for 70-80% of the total annual load.

The total crop production of China was 4.42×10^8 t in 1992, and reached 4.94×10^8 t in 1997 and 5.1×10^8 t in 1999 (National Bureau of Statistics 1999, 2000). The application of chemical fertilizers increased from 8.84×10^6 t in 1978 to 39.8×10^6 t in 1997, of which nitrogen fertilizer comprises 21.7×10^6 t, phosphorus fertilizer 6.98×10^6 t, potassium fertilizer 3.22×10^6 t and compound fertilizer amounts to 7.98×10^6 t (State Statistical Bureau 1997, 1998). Accordingly, some rivers in the country have high levels of nutrients. For example, the DIN concentration of the Changjiang and Huanghe has doubled in last two to three decades, and reached ~100 μM in 1990s (Zhang *et al.* 1995, 1999). Wastewater from industry was 23.5×10^9 t in 1991, with 63.5% pretreated before discharge. In 1997 industrial wastewater was reduced to 18.8×10^9 t, and 84.7% of this wastewater was pretreated before discharge (State Statistical Bureau 1998).

The coastal area of China amounts to 28×10^4 km^2, plus 2.1×10^4 km^2 of beach area. Shallow water culture area is 71.6×10^4 ha, beach 55.6×10^4 ha. The fishing grounds on the adjacent continental shelf cover 2.8×10^8 ha, of which the Bohai accounts for 7.7×10^6 ha, the Yellow Sea 35.3×10^6 ha, the East China Sea 54.9×10^6 ha and the South China Sea 182.1×10^6 ha (State Statistics Bureau 1997, 1998).

Chinese rivers

Due to the climatic variability and uneven water resources for the vast country, water engineering works and natural disasters have significantly altered most Chinese Rivers (Figure 2.4).

The *Huanghe (Yellow River)* is currently the second largest river in the world in terms of sediment load into the sea. Until 3000 years before present (B.P.), the Huanghe had 10% of the present level of suspended sediment and channel shifts were very rare. From 800 years B.P., it became extremely turbid due to cultivation and erosion over the Loess Plateau. Initially, the Huanghe discharged into the Bohai Sea and sediment was transported to the Yellow Sea through the Bohai Strait, with perhaps less than 1% of the river discharge of the suspended sediment transported into the Yellow Sea. However, in 1126 AD the river course shifted into the Yellow Sea because the southern side of the river embankment in Kaifeng City was removed. The Huanghe then discharged its sediment directly into the Yellow Sea. In 1855, the Huanghe changed its course to the north and discharged into the Bohai again. The ever-increasing population and agricultural activities have demanded more water resources, leading to the construction of 18 dams along the river and this modification of the river course has decreased the freshwater discharge significantly. The no-water discharge days increased from 12 to 133 days a year between 1972 and 1996 (Yang *et al.* 1998). Water discharge decreased from 47.2 to $17.0\text{x}10^9 m^3$ yr^{-1} in the 11 years between 1953 and 1963 and sediment load decreased from 1.20 to $0.41\text{x}10^9$ t yr^{-1} between 1986 and 1992 at Lijin hydrographic station (Yang *et al.* 1998).

The *Changjiang* is the fourth largest river in the world in terms of water flow (30,000 m^3 s^{-1}) and sediment load ($500\text{x}10^6$ t yr^{-1}), with large inter-annual variations (Shen *et al.* 1998). A number of natural lakes, e.g., Dongtinghu and Poyanghu along the Changjiang, have a profound effect on both water and sediment discharge into the East China Sea (Shi *et al.* 1985). Large reservoirs were built in 1968 (Danjiangkou Dam), 1981 (Gezhou Dam), and begun in 1997 (Three Gorges Dam). The diversion of 1,000 m^3 s^{-1} of water from the lower Changjiang to North China has been under consideration. The construction of the dams reduced sediment transport downstream. After construciton of the Danjiangkou reservoir in 1968, the annual suspended sediment discharge was reduced from 100 to 1.3×10^6 t yr^{-1} for the Hanjiang – one of the major tributaries of Changjiang from the north – a reduction of 99%. Deforestation in Sichuan has been occurring since 1954 and only 13% of the surface area of Sichuan was still under forest in 1978. Sediment yield in the three northern tributaries of the Sichuan was thus very high due to serious soil erosion (Shi *et al.* 1985). Therefore, the sediment dynamics of the Changjiang estuary and the adjacent shelf must be considerably affected by these reservoirs.

The *Huaihe* discharges 53-700x10^8 m^3 yr^{-1} of water into the Yellow Sea. Over the drainage basin, the rainfall from June to September accounts for 60-70% of annual precipitation and summer floods cause economic damage and death. The Huanghe took the course of Huaihe in 1194-1855, i.e., for a period of ca. 661 years, then formed a huge abandoned delta region on the western coast of Yellow Sea. In the watershed, the cultivated land is 13.3x10^4 km^2 with a population of 130 million. About 35 large and 150 medium reservoirs were constructed along the river course during the last 50 years, with a total capacity of 25.0x10^9 m^3. Today, the Huaihe discharges into Hongzehu and the Jing-Hang Grand Canal, and hence its water flow into the Yellow Sea is quite limited (Committee of Geographic Glossary in China 1996).

The *Minjiang* takes its water source from the Wuyishan in south-east China. Its drainage area is essentially in the subtropical monsoon area. The rainfall in this region is 1500-2500 mm yr^{-1}, with a mean runoff of 1022 mm. In the lower reaches, the ratio between maximum and minimum water flow is 3:1, and the river flow in April – September is 80% of annual discharge. The historical flood record was 29.4x10^3 m^3 s^{-1} in 1968. The vegetation over the watershed is well developed and the river TSM is 50-100 mg l^{-1} (Xiong *et al.* 1989). In the Minjiang drainage basin, the cultivated land area is 55x10^4 ha, with irrigated area 38x10^4 ha and forest 350x10^4 ha. About 150-200 hydropower stations have been constructed over the drainage basin (Xiong *et al.* 1989).

The *Yalujiang* is forms part of the border of China and North Korea. The long-term average water discharge of the Yalujiang estuary is 1200 m^3 s^{-1} (Zhang *et al.* 1998). Four dams and reservoirs have been constructed since 1941 for water management and electrical power production. Due to the presence of the dams, the riverine sediment load is rather limited, averaging ca. 5 x10^6 t yr^{-1} and its suspended matter concentrations can be as low as 5-10 mg l^{-1}. The lower reaches of the river receive a considerable amount of wastes from both non-point (e.g., agriculture) and point (e.g., domestic and industrial activities) sources. The major cities of Dandong and Sinuiju, close to the river mouth, discharge as much as 1x10^6 t yr^{-1} wastewater and high nutrient concentrations (e.g., 900 μM of NO_3^-) have been recorded in the river (Zhang *et al.* 1998).

Korea

The total combined population of South and North Korea increased from 51 million in 1975 to 70 million in 1999 with an annual growth of 0.90% (1995), and 66.23% of the total population live in South Korea. As of 1999, the estimated population of Korea was 46.8 million with a population density of 471 persons km^{-2}, which ranks as one of the highest in the world (along with Bangladesh, the Netherlands and Belgium). Korea's urbanization rate is 78.5% (1995). Land use in South Korea may be summarized as 15,119 km^2 for urban and suburban area, 12,218 km^2 for farmland, and 65,325km^2 for forest in 1997 (Ministry of Environment 1997). The area of cultivated land has decreased from 2.3 to 1.9 x10^6 ha (ha=10^4 m^2) from 1970 to 1997. Energy consumption has increased from 11.7 to 53.9x10^9 t of coal, 71.0 to 748.5 x10^6 bbl of oil, while use of firewood and other energy sources has decreased from 14.7x10^3 t in 1971 to 1.3x10^3 t in 1997 in South Korea. CO_2 emission increased from 146.1x10^6 t in 1981 to 218.3 x10^6 t in 1996, SO_2 decreased from 1.6x10^6 t from 1991 to 1.4x10^6 t to 1997, NO_2 increased from 0.9x10^6 t in 1991to 1.3x10^6 t in 1997. As much as 481.5x10^6 t yr^{-1} of nitrogen fertilizer and 237.6x10^6 t yr^{-1} of phosphorus fertilizer was applied to the croplands from 1975 to 1997. Pesticides shipment has increased from 3.7 to 24.8x10^6 t from 1970 to 1997. The agricultural area specific application of N and P fertilizers and pesticides is 21,945 N t, 9,781 P t, and 1.2 t of pesticides km^{-2} yr^{-1} (Ministry of Environment 1998). However, the percentage of fertilizers and pesticides carried into the coastal ocean of that applied in the agricultural land has not been quantified.

Water resources in South Korea are fairly limited. South Korea gets an average of about 1,274 mm annually, which is 30% more than the world average, 973 mm. This seems abundant, but due to the high population density, the average annual precipitation *per capita* is 2,755 m^3 which is only 12% of the world average of 22,096 m^3. Since two-thirds of the annual precipitation is concentrated between June and September, there are floods in summer and droughts in winter and spring, which is a typical feature of the East Asian monsoon climate. Tropical cyclones often invade the Korean Peninsula in July and August (Kim *et al.* 1998). These typhoons can bring significant amounts of water to the region at an average 13 mm h^{-1} (Bong 1996). Water resources in Korea largely depend on precipitation ($126.7x10^9$ m^3 of precipitation and 1.6 $x10^9$ m^3 of groundwater). However, $57x10^9$ m^3 (45%) of total precipitation is lost in the form of infiltration and evaporation, and about $69.7x10^9$ m^3 (55%) is estimated to be annual surface runoff. Of this amount, $46.7x10^9m^3$ (37%) is swept away by floods immediately after rainfall and the remaining $23x10^9$ m^3 (23% of total precipitation) constitute normal flow. Also, $30.1x10^9$ m^3 (24% of total precipitation) are used for municipal use ($6.2x10^9m^3$), industrial use ($2.6x10^9$ m^3), agricultural use ($14.9x10^9m^3$), and environmental use ($6.4x10^9$ m^3) annually. For supply of water during the dry season, ca. $7.1x10^9m^3$ of water is stored in reservoirs around the country. Daily water supply per person has increased from 256 L per person in 1980 to 309 L per person in 1994, and wastewater discharge per person has increased from 180 to 314 L per person daily from 1980 to 1993. Therefore, generation of domestic sewage has increased from $6.8x10^6$ m^3 in 1980 to $16.0x10^6$ m^3 day^{-1} in 1994. *Per capita* domestic water use is expected to rise from 409 liters in 1997 to 480 liters in 2011. Industrial water use is expected to increase from $2.6x10^9$ m^3 in 1994 to $4.5x10^9$ m^3 in 2011 (Korea Water Resources Corporation 2000). Municipal sewage has been contaminated with domestic and industrial wastewater. Urbanization has increased from 68.7% in 1980 to 84.4% in 1994. Industrialization has been also rapid. Manufacturing industry has increased by a factor of 5 from 1981 to 1997. The industrial production index (total 10,000) was composed of mining (58.7), manufacturing (9,439.4), electricity and gas (501.9) in 1995. The overuse of fertilizers, pesticides and insecticides, and feces and urine of livestock in farming areas has led to serious pollution of rivers and streams nationwide, although these effects have not been quantified yet.

Shallow-water aquaculture has increased a factor of two from 1978 to 1998 and its production was $78x10^6$ t yr^{-1} at 1998 (Ministry of Maritime Affairs and Fisheries 2000) over an area of 100,000 ha, contributing ca. 30% of the national total marine fisheries products (Chang and Hong 1991).

Korean rivers

Major characteristics of rivers in Korea are as follows:

(1) The river reaches are relatively short and channel slopes are relatively steep. The drainage areas are small in Korea compared with other major continental rivers. The channel slopes are relatively steep in the upper reaches because of high mountains and deep valleys in the uplands.
(2) Floods occur quickly and peak flood discharges are enormous. Due to the topographical conditions and torrential rainfall, the hydrographs of rivers in Korea are very sharp and peak flood discharges are enormous compared with comparable rivers on other continents.
(3) Flow variations are high. The coefficients of the river regime, expressed by maximum discharge over minimum discharge for rivers, in Korea usually range from 300 (the Keum River) to 400 (the Han River) and 500 (the Yeongsan River). This large variation in flow discharge causes serious problems for river management, especially flood control and water use. In comparison, this river regime coefficient is 22 and >200 in the Changjinag and the Huanghe (Korea Water Resources Corporation 2000).

Relatively long rivers with complicated dendritic drainage patterns flow westward into the Yellow Sea. Representatives are Aprock (Yalujiang), Chongchon, Taedong, Han, Kum and Yeongsan. The Somjin and Nakdong rivers flow southward. Alluvial plains are mostly developed along these rivers, partitioned by the ramified ranges of the Sinian and Liaodong mountains. They occupy rather small and narrow areas, but occasionally coalesce to form broad plains, typically close to coastal regions (Lee 1987). Due to the steep slope in the upper reaches and the high river regime coefficient, sediment yields are relatively high (Table 2.1). They average 413 ± 33 t km^{-2} yr^{-1} over the whole watershed for the rivers flowing into the Yellow Sea.

Three Gorges Dam on the Changjiang River and primary productivity in the coastal seas

Many state changes are expected to occur after the completion of Three Gorges Dam (TGD) on the course of the Changjiang, including changes in the water regime and reduction of nutrients and sediments supply to the estuary. Chen (2000) calculated the nutrients budget for the East China Sea (ECS) and estimated that total riverine input of P amounts to only a small fraction of the external P supply to the ECS. While a reduction of P flowing out of the Changjiang is not very significant, the fact that the completion of the dam will affect the fresh water regime is critical. It is not yet known how much the TGD will reduce the Changjiang sediment load. Cutting back the Changjiang outflow by a mere 10% would reduce the cross-shelf water exchange by roughly 9% based on the water and salt balances. In that case, the on-shore nutrient intrusion would be reduced by that much as well, if there is a simple linear feedback. This means that whole ecosystem in the ECS would be modified through the food-web proportionately (Zhang *et al.* 1999) as well as the silica dynamics in the Sea of Japan. For the Yellow Sea, the 10% reduction of the Changjiang due to the TGD completion would increase the residence time of water by about 10% (Hong *et al.*, this report).

Area 3: Sea of Japan, Sea of Okhotsk, Bering Sea

Due to the lack of pertinent data, a detailed description on the driver-pressure-state change relationship is not possible at this moment. However, some information on the environmental state of the Sea of Japan can be looked up in Kachur and Tkalin (2000).

Driver-Pressure-State Change relationships in East Asia

As a starting point for a description of the regional DPSIR scenarios, a matrix of causes and effects (Table 2.7) was created to provide an overview of the major drivers affecting drainage basins of different sizes, the mechanisms whereby the resulting pressures affect the coast, the specific effects observed and the timing of these state changes.

Large basin rivers are the least affected by urbanization but strongly affected by agricultural activities, damming and deforestation. Medium basins are affected moderately strongly by agricultural activities, damming and deforestation. Small basins are strongly influenced by urbanization, agriculture, industrialization, aquaculture and marine mining.

Another important aspect is the timing of the related changes in the coastal zone. With the exception of terrestrial gold-mining and marine mining of sand and petroleum which is discrete, most environmental changes occurring in the coastal zone will be progressive, calling for medium to long-term monitoring programmes to be established in order to fully understand those changes and eventually propose alternatives.

Table 2.7 DPSIR matrix characterizing major catchment-based drivers/pressures and a qualitative ranking of related state changes impacting the coastal zone of East Asia *versus* catchment size class.

State change dimension: major; medium; minor; no impact; ? = insufficient information.

Time scale: p = progressive ; d = discrete

Driver	Pressures	State change (qualitative index)				Impact on the coastal system	Time scale
		Large basins	Medium basins	Small basins: active coast	Small basins: passive coast		
Urbanization	Increased food and energy demand. Increase of nutrient-, metal- and BOD-rich waste effluents. Increasing water extraction. Marine and terrestrial renewable (biological production, tourism) and non-renewable resources (e.g., space) exploitation	minor	minor	major	major	• Pollution (POPs and metals) • Eutrophication • Habitat loss/modification • Harmful algal bloom • Accelerated rates of biodiversity loss at the coastal region and adjacent continental platform	p
Agriculture	Waste/nutrient (excess fertilizer), BOD , pesticides effluent increase. Sediment load and water extraction increase. Reclamation increases for agriculture, Loss of good agricultural land due to change of land use. Poor agricultural practices result in poor soil conservation. Over-grazing results in increase of sediment yield (northern region)	medium - major	(minor-) major	(minor-) major	major	▪ Erosion ▪ Habitat loss and/or modification ▪ Harmful algal blooms ▪ Flooding ▪ Pollution with pesticides ▪ Sedimentation due to accelerating upland erosion rates	p
Damming	Freshwater, nutrient and sediment sequestration. Changing hydrological cycle.	major	medium - major	medium	medium - major	▪ Coastal erosion ▪ Decrease in freshwater discharge to estuary ▪ Nutrient depletion in coastal areas without major population, worsening eutrophication in coastal areas with major population due to decrease in water discharge ▪ Change of N/P/Si ratio leads to ecosystem shift ▪ Salt water intrusion in coastal aquifer ▪ Salinization of estuary	d

Table 2.7 continued

Industrializ-ation	Population growth. Food and energy demand. Waste and heat effluent. Water extraction	minor	minor		major	▪ Pollution, heavy metals and organic-micropollutants ▪ Harmful algal blooms	p
Deforestation	Siltation. Sediment and nutrient budget alteration. Water shortage (water balance alteration). Increased frequency of floods and droughts (southern sub-region and the Yangtze basin only)	major	major		major	▪ Habitat loss and/or modification. ▪ Erosion ▪ Flooding ▪ Saltwater intrusion ▪ Biodiversity reduction	p
Aquaculture	Global issue in the region Increase of nutrient-rich and DBO-rich waste effluents from freshwater and saltwater aquaculture. Increased disease spreading	medium - major	medium	major	major	• Eutrophication, Harmful algal blooms • Biodiversity reduction • Habitat loss and/or modification ▪ Introduction of exotic species	
Land reclamation	Sediment budget alteration Change of hydrological cycle	minor	medium	medium	medium	• Saltwater intrusion	p
Marine mining (sand and petroleum)	Sediment budget alteration. Sediment segregation. Water level alteration	n.a.	n.a.		major	• Habitat loss and/or modification • Biodiversity reduction • contamination	d
Mining on land	Increase in sediment transport	minor - medium	minor		minor	• Sedimentation • Habitat loss and/or modification	d

2.6. Assessment of land-based drivers

An assessment of land-based drivers and their related coastal impacts was performed considering different scales (catchment, sub-regional and regional) and ranked according to a relative category. Two divisions were made: catchment and sub-regional scale, and full regional scale.

The ranking takes into consideration the present dimensions of the impacts and their evolution under scenarios constructed on existing data and statistics. This evaluation is incomplete, since most large rivers suffer from a lack of sufficient scientific data and long-term monitoring, while many smaller rivers are not considered in detail. Generally, in East Asia, water resource issues are most important followed by a series of sediment-related issues and finally aspects of water quality.

Catchment and sub-regional scale

The major coastal issues identified in the workshop and their respective drivers are listed in Table 2.8, which shows a ranking-list importance of the impacts caused on coastal areas by basin activities and their trend expectations on the catchment/sub-regional scale. Typological upscaling using indices for the expected trends would be valuable for the identification of future hot spots.

The major coastal issues are eutrophication/red tides, harmful algal blooms, erosion, coastal flooding, saltwater intrusion, pollution and loss/modification of biodiversity. The responsible drivers and the trends expected are summarized here. Sometimes drivers are identified as a lack of management in the region. A more practical way to enforce the existing legislation may be needed in that region. Eutrophication/red tides in the coastal zone are due to agriculture/aquaculture, urbanization/industrialization and lack of management. Erosion is caused by agriculture/aquaculture, damming, deforestation, land reclamation, sediment mining and sea-level rise/land subsidence.

Agriculture/aquaculture will continue to aggravate coastal eutrophication in most of East Asia except Japan and Korea where their influence has not increased in recent decades. However, urbanization/industrialization will be a major contributor throughout East Asia. Agriculture is only significant in the Huanghe, Yangtze and Lia rivers of China. The effects of damming will increase in Vietnamese small rivers and the Huanghe and Yangtze rivers of China. The influence of deforestation will decrease.

Coastal flooding is a result of deforestation, land reclamation and lack of management. The influence of deforestation will decrease, but land reclamation will increase in Vietnam and South China.

Saltwater intrusion occurs due to agriculture, damming, deforestation and sediment mining. Deforestation will decrease in the near future, but the other drivers will be stable.

Pollution is caused by agriculture/aquaculture, urbanization/industrialization, exploitation of mineral resources both in the terrestrial and offshore areas, deforestation and land subsidence. Agriculture/aquaculture and urbanization/industrialization will increas, while mineral exploration will decrease with time. Therefore, the coastal waters will be more polluted in the near future.

Loss/modification of biodiversity stems from land reclamation, aquaculture/agriculture, deforestation, urbanization/industrialization, damming and exploitation of mineral resources. Aquaculture/agriculture, urbanization/industrialization and exploitation of mineral resource including offshore oil will continue to threaten biodiversity in the coastal zone. Effects of deforestation will decrease. However, land reclamation and damming will be stable.

Table 2.8 The link between coastal issues/impacts and land-based drivers in East Asian coastal zones - Overview and qualitative ranking on local, catchment and sub-regional scale.

Category: 1 = low; 10 = high. (1= no impact, 10= very serious impact.) Trends: ⇒ = stable, ⇑ = increasing, ⇓ = decreasing.

Coastal Impact/ Issues	DRIVERS	Local catchment (allowing within and between catchment comparison)		Trend expectations	References/ Data sources
		River	Category		
Eutrophication/ red tides	Agriculture/aquaculture	▪ Small rivers in South China (Hanjiang and Nandujiang)	3	⇑	Refer to relevant contributed paper
		▪ Pearl River, Vietnam	9		
		▪ Red River, Vietnam	1		
		▪ Vietnamese small rivers	1		
		▪ Mekong River, Vietnam	2		
		▪ Yangtze River, China	8		
		▪ Lao River, China	8	⇑	
		▪ Hai River, China	8	⇑	
		▪ Japanese Islands	10	⇒	
		▪ Korean small rivers (west and southern)	9	⇒	
		▪ Tumen River, North Korea/Russia/China	1	⇑	
	Urbanization/ industrialization	▪ Small rivers in South China (Hanjiang and Nandujiang)	3	⇑	Refer to relevant contributed paper
		▪ Pearl River, Vietnam	9		
		▪ Red River, Vietnam	1		
		▪ Vietnamese small rivers	1		
		▪ Mekong River, Vietnam	2		
		▪ Yangtze River, China	8		
		▪ Lao River, China	8		
		▪ Hai River, China	9-10		
		▪ Japanese Islands	10	⇓	
	Lack of management	▪ Small rivers in South China (Hanjiang and Nandujiang)	2		Refer to relevant contributed paper Regulation enforcement
		▪ Pearl River, Vietnam	8		
		▪ Red River, Vietnam	9		
		▪ Vietnamese small rivers	8		
		▪ Mekong River, Vietnam	9		

Table 2.8 continued

Erosion	Agriculture/aquaculture	▪ Small rivers in South China (Hanjiang and Nandujiang)	2		Refer to relevant contributed paper
		▪ Pearl River, Vietnam	1	⇒	
		▪ Red River, Vietnam	1		
		▪ Vietnamese small rivers	1		
		▪ Mekong River, Vietnam	2		
		▪ Yellow River, China	9		Yang *et al.* (1998)
		▪ Yangtze River, China	8		Duan (2000)
		▪ Lao River, China	6		Xing (workshop*)
	Damming	▪ Small rivers in South China (Hanjiang and Nandujiang)	8	⇑	Refer to relevant contributed paper
		▪ Pearl River, Vietnam	2	⇒	
		▪ Red River, Vietnam	10	⇒	
		▪ Vietnamese small rivers	7	⇑	
		▪ Mekong River, Vietnam	5	⇒	
		▪ Yellow River, China	10	⇑	Yang (workshop*)
		▪ Yangtze River, China	10	⇑	Xi *et al.* (1994)
	Deforestation	▪ Small rivers in South China (Hanjiang and Nandujiang)	4		Refer to relevant contributed paper
		▪ Pearl River, Vietnam	1	⇓	
		▪ Red River, Vietnam	9		
		▪ Vietnamese small rivers	9		
		▪ Mekong River, Vietnam	7		
		▪ Yellow River, China	8	⇒	
		▪ Lao River, China	6	⇒	Xing (workshop*)
	Land Reclamation	▪ Small rivers in South China (Hanjiang and Nandujiang)	3		Various papers
		▪ Pearl River, Vietnam	2	⇒	
		▪ Red River, Vietnam	9		
		▪ Vietnamese small rivers	5		
		▪ Mekong River, Vietnam	4		
	Sediment mining	▪ Small rivers in South China (Hanjiang and Nandujiang)	9		?
		▪ Pearl River, Vietnam	2	⇒	
		▪ Red River, Vietnam	2		
		▪ Vietnamese small rivers	5		
		▪ Mekong River, Vietnam	1		
	Sea-level rise/ Land subsidence	▪ Yellow River	9	⇒	Yang (workshop*)
		▪ Yangtze River	4		
		▪ Liao River, China	8	⇑	Xing (workshop*)
		▪ Hai River, China	10	⇑	Xing (workshop*)

Table 2.8 continued

Flooding	Deforestation	▪ Small rivers in South China (Hanjiang and Nandujiang) ▪ Pearl River, Vietnam ▪ Red River, Vietnam ▪ Vietnamese small rivers ▪ Mekong River, Vietnam	2 2 7 9 5	⇓	Refer to relevant contributed paper
	Land reclaimation	▪ Small rivers in South China (Hanjiang and Nandujiang) ▪ Pearl River, Vietnam ▪ Red River, Vietnam ▪ Vietnamese small rivers ▪ Mekong River, Vietnam	7 8 7 2 7	⇑	Refer to relevant contributed paper
	Lack of management	▪ Small rivers in South China (Hanjiang and Nandujiang) ▪ Pearl River, Vietnam ▪ Red River, Vietnam ▪ Vietnamese small rivers ▪ Mekong River, Vietnam	8 8 8 8 8	⇒ ⇒ ⇓ ⇓ ⇓	National regulations
Saltwater intrusion	Agriculture	▪ Small rivers in South China (Hanjiang and Nandujiang) ▪ Pearl River, Vietnam ▪ Red River, Vietnam ▪ Vietnamese small rivers ▪ Mekong River, Vietnam	1 8 8 5 4	⇒	Refer to relevant contributed paper
	Damming	▪ Small rivers in South China (Hanjiang and Nandujiang) ▪ Pearl River, Vietnam ▪ Red River, Vietnam ▪ Vietnamese small rivers ▪ Mekong River, Vietnam	1- 2 4 8 7 5	⇒	Refer to relevant contributed paper
	Deforestation	▪ Small rivers in South China (Hanjiang and Nandujiang) ▪ Pearl River, Vietnam ▪ Red River, Vietnam ▪ Vietnamese small rivers ▪ Mekong River, Vietnam	2 2 4 5 2	⇓	Refer to relevant contributed paper
	Sediment mining	▪ Small rivers in South China (Hanjiang and Nandujiang) ▪ Pearl River, Vietnam ▪ Red River, Vietnam ▪ Vietnamese small rivers ▪ Mekong River, Vietnam	4 9 1 2 0	⇒	?

Table 2.8 continued

Pollution	Agriculture /aquaculture	▪ Small rivers in South China (Hanjiang and Nandujiang)	8	⇑	Refer to relevant contributed paper
		▪ Pearl River, Vietnam	9		
		▪ Red River, Vietnam	7		
		▪ Vietnamese small rivers	5		
		▪ Mekong River, Vietnam	6		
		▪ Yangtze River, China	8		
		▪ Korean rivers	7		
		▪ Anadir River, Russia	1		
		▪ Amur River, Russia	3		
	Urbanization/ Industrialization	▪ Small rivers in South China (Hanjiang and Nandujiang)	8	⇑	Refer to relevant contributed paper
		▪ Pearl River, Vietnam	9		
		▪ Red River, Vietnam	6		
		▪ Vietnamese small rivers	5		
		▪ Mekong River, Vietnam	6		
		▪ Yangtze River, China	8		
		▪ Liao River, China	8		
		▪ Japanese rivers	6-10		
		▪ Korean rivers	6		
		▪ Amur/small rivers, Russia	2-3		
	Exploitation of mineral resources (including terrestrial mining and offshore oil exploration)	▪ Small rivers in South China (Hanjiang and Nandujiang)	3	⇒	Refer to relevant contributed paper
		▪ Pearl River, Vietnam	6		
		▪ Red River, Vietnam	4		
		▪ Vietnamese small rivers	3		
		▪ Mekong River, Vietnam	5		
		▪ Amur/small rivers, Russia	2		
		▪ Anadir River, Russia	1	⇑	
	Deforestation	▪ Amur/small rivers, Russia	3	⇑	
Land subsidence	Agriculture/groundwater pumping	▪ Liao River, China	8	⇑	Xing (workshop*)
		▪ Hai River, China	10	⇑	Xing (workshop*)

Table 2.8 continued

Loss/ modification of biodiversity	Land reclamation	▪ Small rivers in South China (Hanjiang and Nandujiang) ▪ Pearl River, Vietnam ▪ Red River, Vietnam ▪ Vietnamese small rivers ▪ Mekong River, Vietnam ▪	2-3 3-8 8 9 6	⇒	Refer to relevant contributed paper
	Aquaculture/ agriculture	▪ Small rivers in South China (Hanjiang and Nandujiang) ▪ Pearl River, Vietnam ▪ Red River, Vietnam ▪ Vietnamese small rivers ▪ Mekong River, Vietnam ▪ Yangtze River, China	4 9 9 10 9 4	⇑	
	Deforestation	▪ Small rivers in South China (Hanjiang and Nandujiang) ▪ Pearl River, Vietnam ▪ Red River, Vietnam ▪ Vietnamese small rivers ▪ Mekong River, Vietnam	2 2 4 8 4	⇓	
	Urbanization/ industrialization	▪ Small rivers in South China (Hanjiang and Nandujiang) ▪ Pearl River, Vietnam ▪ Red River, Vietnam ▪ Vietnamese small rivers ▪ Mekong River, Vietnam ▪ Yangtze River, China	9 9-10 6 8 6 3	⇑	Refer to relevant contributed paper
	Damming	▪ Small rivers in South China (Hanjiang and Nandujiang) ▪ Pearl River, Vietnam ▪ Red River, Vietnam ▪ Vietnamese small rivers ▪ Mekong River, Vietnam ▪ Yangtze River, China	4 4 5 4 4 5	⇒ ⇑	Refer to relevant contributed paper
	Exploitation of mineral resources	▪ Small rivers in South China (Hanjiang and Nandujiang) ▪ Pearl River, Vietnam ▪ Red River, Vietnam ▪ Vietnamese small rivers ▪ Mekong River, Vietnam	2 2 8 6 7	⇑	Refer to relevant contributed paper

* - information was supplied during the workshop but references not provided.

Regional scale

The major coastal issues identified in the workshop and their respective drivers on a regional scale are listed in Table 2.9, which shows a ranking-list importance of the impacts caused on coastal areas by basin activities and their trend expectations on a regional scale. Typological upscaling using indices for the expected trends would help identify potential hot spots.

The major coastal issues are eutrophication/red tides and harmful algal blooms, erosion, coastal flooding, saltwater intrusion, pollution and loss/modification of biodiversity. The responsible drivers and the trend expected on the regional scale are summarized here. Eutrophication/red tides in the coastal zone are caused by agriculture/aquaculture, urbanization/industrialization and lack of management. Erosion is a result of agriculture/aquaculture, damming, deforestation, land reclamation, sediment mining and sea-level rise/land subsidence.

The qualitative ranking and trend expectation are as discussed for the catchment and sub-regional scale.

Table 2.9. The link between coastal issues/impacts and land-based drivers in the coastal zones of East Asia – Overview and qualitative ranking on local, sub-regional or country scale.

Category: 1 = low; 10 = high. (1= no impact, 10= very serious impact.) Trends: ⇒ = stable, ⇑ = increasing, ⇓ = decreasing.

Coastal Impact/ Issues	Drivers	Regional scale		Trend-expectation	References/ data sources
		Sub-region	Category		
Erosion	Agriculture	a. Vietnam and southern China b. Central China c. Northern East Asia	1-2 7-9 2	⇒ ⇒ ⇒	Contributed papers in this report
	Damming	a. Vietnam and southern China b. Central China	2-10 10	⇒, ⇑ ⇑	
	Deforestation	a. Vietnam and southern China b. Central China c. Northern East Asia	1-9 8 2	⇓ ⇒ ⇑	
	Land reclamation	a. Vietnam and southern China	2-9	⇒	
	Sediment mining	a. Vietnam and southern China	1-9	⇒	
	Sea-level rise/ land subsidence	a. Central China b. Taiwan Island	4-9 8	⇒, ⇑ ?	
Eutrophication	Agriculture/Aquaculture	a. Vietnam and southern China b. Central China inlcuding Korea c. Northern East Asia	1-9 8-10 1-2	⇑ ⇒ ⇑	
	Urbanisation/industrialization	a. Vietnam and southern China b. Central China including Japan Island	1-9 9-10	⇑ ⇑	
	Lack of management	a. Vietnam and southern China	2-9		Contributed papers in this report, regulation enforcement

Table 2.9 continued

Flooding	Deforestation	a. Vietnam and southern China b. Northern East Asia	2-9 2-3	⇓ ⇑	
	Land reclamation	a. Vietnam and southern China	2-8	⇑	
	Lack of management	a. Vietnam and southern China	8	⇒, ⇓	
Saltwater intrusion	Agriculture	a. Vietnam and southern China	1-8	⇒	
	Damming	a. Vietnam and southern China	1-8	⇒	
	Deforestation	a. Vietnam and southern China	2-5	⇓	
	Sediment mining	a. Vietnam and southern China	0-9	⇒	
Pollution	Agriculture/aquaculture	a. Vietnam and southern China a. Central China and Korea b. Northern East Asia	5-9 7-8 1-3	⇑	
	Urbanization/industrialization	a. Vietnam and southern China b. Cental China, Japan, Korea c. Northern East Asia	5-9 6-10 2-3	⇑	
	Exploitation of mineral resources (including terrestrial and offshore oil exploration)	a. Vietnam and southern China b. Northern East Asia	3-6 1-4	⇒ ⇒	
	Deforestation	a. Northern East Asia	3	⇑	
Land subsidence	Agriculture/groundwater pumping	a. Central China b. Taiwan Island	8-10 8	⇑ ⇑	
Loss/modification of biodiversity and habitat	Land reclamation	a. Vietnam and southern China	2-9	⇒	
	Aquaculture/agriculture	a. Vietnam and southern China b. Central China	4-10 4	⇑	
	Deforestation	a. Vietnam and southern China	2-8	⇓	
	Urbanization/industrialization	a. Vietnam and southern China b. Central China	6-10 3	⇑	
	Damming	a. Vietnam and southern China b. Central China	4-5 5	⇒ ⇑	
	Exploitation of mineral resources	a. Vietnam and southern China	2-8	⇑	

2.7 Policy and management response

A general summary of the scientific and/or management response to coastal impact/issues in East Asia on catchment, sub-regional and regional scales is presented in Table 2.10. Monitoring and research efforts differ in nature and intensity according to country. There is a general lack of long-term data and inter-regional comparisons. Determining changes in loads and deriving the "critical loads" to the coastal zone is thus far from a trivial effort, being based on the processing of at times very limited information. Most monitoring programs began in the 1980s and have at the most been going for 20 years. From the LOICZ workshop on estuarine systems of the East Asian Region (Smith *et al.* 2000, Buddemeier *et al.* 2002), fluxes of carbon, nitrogen and phosphorus were estimated for a variety of estuarine systems in East Asia. Although very restricted geographically, this exercise may be a key step in the typology of the continent's coasts. An overview of the ongoing efforts is presented here.

Area 1: South China Sea

Vietnam
In Vietnam, the main rivers flowing into the South China Sea are the Mekong and Red rivers. The smaller Ban-Ky Cung, Ma, Ca, Gianh-Tri-Huong, Thu Bon, Tra Khuc, Ba and Dong Nai rivers are also very important for their catchment and receiving coastal regions in terms of the economic welfare of the residents. There are no continuous records of river data to analyze for the future changes. Therefore, it is essential to install a number of monitoring stations in the river paths. It is also necessary to review the existing data to formulate proper management legislation.

South China: Pearl River
The Environmental Protection Bureau of Guandong Province, in conjunction with other urban cities and counties in 1995, has introduced environmental impact assessment and pollutant discharge fees to control pollution and prevent further environmental deterioration. However, due to lack of resources, only USD 0.12 million (0.7% of GDP) has been allocated for environmental improvement, so that only 11% of domestic sewage (0.3x106 m^3) could be treated in 1998 and the rest was discharged into the sea untreated. The economic loss in the region due to environmental degradation amounts to USD 11×10^9 a year (Chan 1998). To restore the water quality of the Pearl River, it is necessary to enforce the pollution regulations and rules within the region including disposal charges and licenses, and to construct more waste treatment plants to reduce the concentration of pollutants in treated sewage/effluent.

The Pearl River Estuary Integrated Observing System (PEIOS) was established in Zhongshan University of Guangzhou in 1999 to evaluate estuarine and coastal ocean forecasting models coupled to a multiplatform sampling network (Wu, this report).

In South China, the Pearl River is the major river flowing into the South China Sea. The Pearl River and its delta have abundant time-series data on flow and coastal morphology. A national program (863 project) monitors the whole Pearl River. The State Oceanic Administration (SOA) has a project with Japanese researchers on the South China Sea. Hong Kong Baptist University and Zhongsan University have a joint project on the uptake and bioaccumulation of heavy metals and PTS (PCB and DDT) by fish. These research results are utilized by the Pearl River Coastal Authority for the management of the Pearl River and its coastal zone. Regionally, a GEF/UNEP project studies the sources, fates and effects of 12 priority pollutants, particularly POPs, in the Pearl River Delta.

Area 2: East China Sea, Yellow Sea, and Bohai

Central China
Flowing into the East China, Yellow and Bohai seas are the Yangtze, Huanghe, Hai and Liao rivers, plus numerous smaller rivers. These rivers has a very long records of river data, therefore the changes in catchment and delta over time have been well documented. More rigorous monitoring of water quality began in 1999. Numerous scientific project on the changes of water and land resources in the Yangtze

River delta, and the balance of arable land changes and its sustainable development have been carried out. The Yantgze River Commission was established many years ago to manage the Yangtze River.

For the Huanghe, erosion-accumulation of sediments and the resulting hazards have been the subjects of a number of projects in recent decades. Utilizing these scientific results, the Commission on Coast Protection From Erosion, Blue Sea Action Program, and the Prevention of Flow-cut-off of the Yellow River have been established by the Shenli Oil Adminstration, the National Bureau of Environmental Protection of China and a local authority, respectively, since 1998. For the Hai and Liao rivers, the interactions between human activities and environment have been studied for a few decades. In order to economize water uses and curb water pollution, water resources in China will be commercialized. Water from the Yangtze River in the south will be diverted to the Hai River.

Japan, Taiwan and Korea
All the rivers are monitored and databases are compiled by the Environment Ministry. Legislation on environmental standards for concentration and flux of each contaminant are enforced.

Area 3: Sea of Japan, Sea of Okhotsk, Bering Sea

The Amur River bordering the Russian Federation and China discharges mainly into the Sea of Okhotsk and to a much smaller extent into the Sea of Japan. The Amur River has been monitored for 3-5 parameters at base stations and 21 parameters at some stations since 1960. However, there are no systematic time-series data available. A jointly-conducted monitoring programme by the Russian Federation and China is necessary. In 1998, the Amur River International Commission was set up.

The Tumen River bordering North Korea, China and the Russian Federation discharges into the Sea of Japan. There are only six monitoring stations in the river, and there is no coordination between the three bordering countries. The Tumen River Area Development Program (TRADP) by UNDP is currently coordinating the environmental protection effort among the participating countries of China, the Russian Federation, Mongolia, North Korea and South Korea.

Table 2.10 Scientific and/or management response to coastal impact/issues in East Asian coastal zones on catchment, sub-regional and regional scale.

River catchment	RESPONSE Catchment scale		RESPONSE Sub-regional/ Country scale		RESPONSE Regional scale	
	Scientific	Management	Scientific	Management	Scientific	Management
Vietnam						
Mekong and Red rivers	Few stations for monitoring. 1 to 2 stations for catchment studies. No system to monitor change from time to time. Lack of scientific data	Need monitoring programmes and regulations from authorities to review what is available.	Fewer stations in south than north	Enforcement less effective from south to north		Mekong River Commission
Small rivers (Ban-Ky Cung, Ma, Ca, Gianh-Tri-Huong, Thu Bon, Tra Khuc, Ba, Dong Nai)	No continuous research Only occasional measurement campaign Very few monitoring stations	No action at all. Only regulations in respond to current/outbreak situation	No continuous research Only occasional measurement campaign Very few monitoring stations	No action at all. Only regulations in respond to current/outbreak situation		

Table 2.10 continued

China						
Pearl River	National level programme (863 project) monitor the whole Pearl River Delta. State Oceanic Administration (SOA) has a project with Japanese on South China Sea. Hong Kong Baptist University and Zhongshan University carrying out a joint project on the uptake and bioaccumulation of heavy metals and PTS by fish (PCB and DDT).	PEIOS in 867 research project. National Programme and Integrated Observing System on Pearl River Estuary. 20 m of water depth coast managed by Pearl River Coastal Authority and SOA.			GEF/UNEP project studies sources, fates and effects on 12 priority pollutants.	Fates of POPs.
Yellow River	Erosion-accumulation hazards project from 1995-2000 funded by MOST of China Evolution of the Huanghe Delta project funded by NSFC, 2000-2002. Program on erosion is reviewing in 2001	Commission on coast protection from erosion was established by the Shenli Oil Administration, 2001. "Blue Sea" action programme in the Bohai Sea from pollution is underway by the National Bureau of Environmental Protection of China Action of preventing flow-cut-off of the Huanghe was taken in 1998				

Table 2.10 continued

Yangtze River	Monitoring of water quality since 1999. The environmental change of water and land resources in the Yangze River Delta project funded by NSFC (1999-2001) Balance of the arable land changes and its sustainable development project funded by Ministry of Land and Resources (1999-2001) Database construction Several universities and institutes have already undertaken various research projects relating river issues	Yangtze River Commission was established many years ago and has accumulated a large data, especially about the middle-upper reach river basin. Monitoring station established. Legislation in place RS and GIS				
Liao River	The influence of human activities on environments has been studied systematically in Liao River valley, particularly in the delta areas for the period of 1987 to 1994.	The prawn culture areas should be strictly controlled in East Liao estuary.				
Hai River	The interactions between human activities and environment have been studied systematically in 1980s and 1990s.	The Chinese Government will start to transfer water from the Yangtze River in the south to the Hai River in the North. The water resources in China will be commercialized in order to economize its uses and curb the water pollution.				

Tale 2.10 continued

Japan						
	Database have been constructed for all rivers by Environment Ministry.	Legislation: environmental standards are set in the river		Legislation: environmental standards are set for concentrations and load of COD, N, P in the bays and coastal seas.		
Taiwan						
	Database have been constructed for all rivers by Environment Ministry	Environmental standards for river water quality are enforced				
Korea						
	Database have been constructed for all rivers by Environment Ministry	Environmental standards for river water quality are enforced				
Russia/ China						
Amur River	Monitoring and measurements since 1960 for 3-5 parameters, basic stations 21 parameters and 5 special stations 50 at present, but not in a systematic way.	Separate management plans by Russia and China, but no joint programs for the whole system.				Amur River International Commission started to work in 1998.
North Korea/ Russia/ China						
Tumen River	1 station in Russia, 1 station in North Korea (now closed), 5 stations in China	No coordination between the countries		Tumen River Area Development Program (TRADP) by UNDP (China, Russian Federation, Mongolia, North Korea, South Korea)		

2.8 Key areas for research projects

"Hot spots" (point sources and current and future pressure areas) of land-based coastal impact and gaps in understanding as well as a first overview of issues to be addressed in future research were drawn from the workshop and are summarized in Table 2.11.

Vietnam and South China

There is no continuous data-set available to analyze the catchment basin activities and marine impacts of the Mekong River. A monitoring network needs to be set up to control flooding and erosion, and standardization is needed of sampling methods, analysis of samples for accurate and comparable data, and to foster the monitoring of capacity-building for manpower and facilities. It is further necessary to develop a holistic multidisciplinary project to harmonize environmental conservation and development among stakeholders including all Mekong states.

The Red River needs a similar project to that of the Mekong River, especially for biogeochemical studies including erosion and flood scales, ecological and economic factors in terms of the human dimension covering both China and Vietnam.

At the national level of Vietnam, more emphasis should be placed on small rivers. A long-term scientific approach to control flooding, erosion and saltwater intrusion related to domestic and agricultural activities is needed.

The Pearl River in South China suffers a lack of basic research, and a mechanism of transferring research results to legislative processes. Dredging sediments from the distributaries of the Pearl River Delta cause outbreaks of red tides. Therefore, research efforts should be focussed on the prediction of red tides and prevention of damage to mariculture. Because of the increased toxic contaminant levels in the environment, biotic model studies are needed on biomagnification in the food-web, e.g., use of biomarkers (fish and human breast milk) to study effects. However, further research is greatly hampered by the lack of funding.

Central China, Japan, Taiwan and Korea

For the Yangtze River, research needs are land-use change and analysis of its drivers, sediment and nutrient flux changes, freshwater discharge change, soil erosion and land degradation research including N, P, S budgets, contamination, biodiversity, dams, the Great Western Development and marine impacts. In order to address hot spots, identification and quantification of temporal and spatial land-use changes and evaluation of human impacts on land-use changes and their consequences are needed. The Yangtze River discharge is so large that it influences the north-eastern marginal seas of the East China and Yellow seas and the southern part of the Sea of Japan, so it is very important to know what kind of changes will occur in the water cycle and the biogeochemical cycle in the Yangtze catchment by damming and in the Great Western Development and receiving marginal seas.

For the Huanghe, a sharp reduction of water and sediment into the sea in recent decades is a major problem. In order to address the flow-cut-off problem, systematic investigation of coastal erosion and the consequences in relation to the change and flux threshold on sediment, C, N, P and Si have to be studied. For the management purpose, impact assessment of the resources, environment and socio-economic sectors has to be conducted to provide rationales for regulation of the water and sediment resources for the whole Huanghe catchment.

The Liao River and the Hai River suffer water shortages and impacts from petroleum and natural gas exploitation. It is necessary to conduct biogeochemical studies and develop water conservation technology for industry and agriculture.

Japan suffers a lack of coastal space for harbours, industry, airports and urban expansion, and a lack of waste disposal sites on land. Conservation of natural coastal ecosystems and wetlands and contamination of seafood due to emission of pollutants through rivers and the atmosphere are major concerns for the Japanese coastal zones. Water quality standards and regulations for concentrations and fluxes of contaminants of chemical oxygen demand (COD), N and P need to be developed. A further reduction of pollutants input from non-point sources is essential in controlling coastal water pollution.

The Taiwanese coastal zone suffers severe water pollution, wetland erosion, land subsidence, freshwater shortage and diminished fish catch. Projects are needed linking these impacts and issues to economic loss and health hazards, to convince policy-makers and the public that economic growth must consider the health of the environment. The effects of the reduced freshwater discharge into the sea on the shelf ecosystem and fisheries must be determined.

Korean coasts suffer from eutrophication and social dispute against land reclamation and the associated environmental changes. Integrated coastal zone management involving all concerned stakeholders has to be based on the sound understanding of the relationships between activities in the river catchment, the terrestrial coastal zone and the marine coastal zone.

Russian Federation

In the Anadir and Amur river basins, knowledge transfer from natural science to social science is badly needed in order to monitor the rivers more systematically, to standardize measurement methods and to analyse the complex variables of sources and transport of materials within the river system.

Sound management of the Tumen River shared by China, North Korea, and Russian Federation requires a knowledge transfer from natural science to social science. An international commission for the protection of the Tumen River is needed to coordinate monitoring methods among countries concerned.

Table 2.11 Hot spots (point source) of land-based coastal impact and gaps in understanding as well as a first overview of issues to be addressed in future research (identifying the appropriate scale for the design of a new scientific effort).

River catchment	Hot Spot Catchment scale		Hot Spot Sub-regional/ Country scale		Hot Spot Regional scale	
	Key issue, trend, and gaps	Scientific approach	Key issue, trend and gaps	Scientific approach	Key issue, trend and gaps	Scientific approach
Vietnam						
Mekong River	No continuous data set available Low frequency of monitoring Lack of common parameters/variables on measurement and analysis Method standardizations are needed for collection of samples, analysis to produce accurate and comparable data. Capacity building for manpower and facilities is needed.	Set up monitoring network to control flood and erosion. Stronger enforcement of some measures to control flooding and deforestation is needed. Develop a holistic multidisciplinary project to harmonize environmental conservation and development among stakeholders.	Same as that of catchment scale	Same as that of catchment scale		

Table 2.11 continued

Red River	No continuous data set available Low frequency of monitoring Lack of common parameters/variables on measurement and analysis Method standardizations are needed for collection of samples, analysis to produce accurate and comparable data. Capacity building for manpower and facilities is needed	Critical review on the current status is on going. Biogeochemical studies, erosion and flood scales, ecological, economic in terms of human dimension.	Same as that of catchment scale	Fix the route of monitoring from Vietnam to China. Same as that of catchment scale.		
Small rivers (Ban-Ky Cung, Ma, Ca, Gianh-Tri-Huong, Thu Bon, Tra Khuc, Ba, Dong Nai)	Lack of data. More emphasis should be placed on small rivers at national levels. Physical, biological and chemical variables should be studied. Salt intrusion (related to domestic and agricultural activities	Set up monitoring stations. Long-term scientific approach to control flood and erosion.				

Table 2.11 continued

China						
Pearl River	Lack of basic research. Research results should be available for legislation. Poor enforcement of existing legislations. Sediments dredged from 8 outlets causing red tides	Find methods to predict red tides and prevent damage in mariculture. Development models to predict impacts Analysis and action plan. Biotic model studies related to biomagnification in food web, e.g. use of biomarkers (fish, human breast milk) to study effects. However, no funding for further research work. Thus difficult to get to advanced stage.				

Table 2.11 continued

Yangtze River	Land use change and analysis of its drivers. Sediment and nutrient flux changes Freshwater discharge change Soil erosion and land degradation research including N,P,S budgets. Contamination. Biodiversity. Dam. Great Western Development.	Biogeochemical studies Modelling ecosystem functions in the basin Establishment of process and systematic models for evolution and predition of land use change Residual calculation by economic sectors. Critical flux investigation Stakeholder and scale analysis Biogeochemical studies Assessment of resources and environment changes including cost-benefit analysis. Prediction of coastal erosion.	Land use change and analysis of its drivers	Identification and quantification of temporal and spatial land use changes and evaluation of human dimensions on the land use changes and their consequences	Dam	Strong interaction exists between the Yangtze River catchment and the East China Sea. It is important to know what kinds of changes will be created in the water and biogeochemical cycles in the Yangtze catchment by damming and Great Western development, and what responses in ecosystem function can be anticipated in the East China Sea and other adjacent seas.

Table 2.11 continued

Yellow River	Sharp reduction of water and sediment into the sea continues.	Systematic investigation of coastal erosion and the consequences relating to the changes. Flux threshold on sediment, C, N, P, Si. Monitoring system and process and modeling studies for coastal changes. Impact assessment on the resources, environment and socio-economic sectors. Regulation on the water and sediment resources for the whole Yellow River catchment.	Same as that of catchment scale	Same as that of catchment scale	Same as that of catchment scale	Same as that of catchment scale
Liao River	Impact of resource (petroleum and natural gas exploitation) development on environment. Rational use of water resource.	Biogeochemical studies. Water conservation technology for industry and agriculture.	Same as that of catchment scale	Same as that of catchment scale		
Hai River	Water shortage in urban area. Over-pumping of groundwater.	Biogeochemical studies. Water conservation technology for industry and agriculture	Same as that of catchment scale	Same as that of catchment scale		

Table 2.11 continued

Japan						
	Lack of coastal space for harbor, industry, airport, urban expansion. Lack of waste disposal sites on land. Conservation of natural coastal zone and wetlands is needed. Contamination of seafood due to emission of pollutants through river and atmosphere.	Water quality standards and regulations are enforced for concentration as well as total flux of COD, N, P. For example, the current pollutant input to Tokyo Bay should be cut by half in order to meet the government regulation. The reduction of pollutant input from the non-point sources is essential in controlling coastal water pollution.	Same as that of catchment scale	Same as that of catchment scale		
Taiwan						
	Severe water pollution, wetland erosion, land subsidence, chemicals, water shortage, diminished fish catch	Linking problem to economic losses and health hazards in order to convince policymakers and the public that economic growth must be in line with the health of the environment. How the reduced freshwater discharge affects the shelves must be determined.	Same as that of catchment scale	Same as that of catchment scale		
Korea						
	Eutrophication. Land reclamation and environmental change	The integrated coastal management involving all concerned stakeholders has to be based on the sound understanding the relationship between the activities in the river catchment and terrestrial coastal zone versus the marine coastal zone.	Same as that of catchment scale	Same as that of catchment scale		

Table 2.11 continued

Russia/China						
Anadyr and Amur rivers	Knowledge transfer from natural science to social science	International commission for the protection of the Amur River monitoring stations.	Standardization of measurement methods and analysis of complex variables of sources and transport of materials within the river system. Knowledge transfer from natural science to social science		Riverine nutrient and sediment fluxes to the individual seas	Data availability International collaboration.
North Korea/Russia /China						
Tumen River	Knowledge transfer from natural science to social science	International commission for the protection of the Tumen River monitoring stations. No coordination between the countries.	Standardization of measurement methods and analysis of complex variables of sources and transport of materials within the river system. Knowledge transfer from natural science to social science.		Riverine nutrient and sediment fluxes to the sea.	

3. ACHIEVEMENTS, OUTLOOK AND FUTURE PROJECTS

by H.H. Kremer, G.H. Hong and Wim Salomons

3.1 Achievements

The first East Asian Basins workshop generated a preliminary picture of land-based activities in the watersheds and their impacts on the coastal zone of the East Asian sub-continent.

Table 3.1 gives a first regional synthesis and qualitative ranking of major land-based activities, the present status of their effects on the coastal zone of the East Asian sub-continent and trend expectations. The major coastal issues were identified as eutrophication/red tides and erosion. However, coastal issues in the individual drainage basins vary, due to the variation in river types, climate and human perturbation. Moreover, most basins lack systematic data-bases on river chemistry and watersheds. A significant gap was found in the data and information bases for large rivers in the southern and northern sub-regions.

The regional assessment provided a comprehensive overview of the current knowledge of catchment–coastal sea interaction in East Asia. The set of indices and qualitative typological classes of drivers and change for each sub-region will be useful for regional and global comparison of DPSIR scenarios. A first approximation of distances of coastal state changes to related thresholds for system functioning was also developed.

Table 3.1 Major activities, present status and trends affecting East Asian coastal zones

Anthropogenic Drivers	Major State Changes and Impact	Present Status	Trend Expectations
Agriculture/aquaculture Urbanisation/ industrialization Lack of management	Eutrophication/ red tides	Major	Stable ⇒ Increasing ⇑ Decreasing ⇓
Damming/Diversion Deforestation Land reclamation Sediment mining Sea-level rise/land subsidence	Erosion/Sedimentation	Major	Increasing ⇑ Decreasing ⇓ Stable ⇒ Stable ⇒ Stable ⇒
Deforestation Land reclamation Lack of management	Coastal flooding	Major	Decreasing ⇓ Increasing ⇑ Stable ⇒
Agriculture Damming Deforestation Sediment mining	Saltwater intrusion	Medium	Stable ⇒ Stable ⇒ Decreasing ⇓ Stable ⇒
Agriculture/aquaculture Urbanization/ industrialization Mining (land and sea) Deforestation Land subsidence	Pollution	Medium	Increasing ⇑ Increasing ⇑ Stable ⇒ Decreasing ⇓ Stable ⇒
Land reclamation Aquaculture/agriculture Deforestation Urbanization/ industrialization Mining	Loss of habitat and biodiversity	Low	Stable ⇒ Increasing ⇑ Decreasing ⇓ Increasing ⇑ Increasing ⇑

The results of this assessment and synthesis will be fed into the first global LOICZ synthesis in late 2002. The regional features and rankings (see Appendix 1) enable interregional comparison and up-scaling within the global LOICZ-Basins network. The tables reflect the results of the plenary discussions about the key questions.

Some of the contributed papers have been developed to full scientific papers for publication in the journal "Regional Environmental Change". This special issue will focus on the interdisciplinary aspects of the human dimensions of catchment-coastal sea interaction in South America and East Asia.

Products from East Asia Basins

This LOICZ R&S Volume providing the first regional picture using the DPSIR framework and paralleling other regional assessments (AfriBasins: Arthurton *et al.* 2002, SAmBas, Lacerda *et al.* 2002, CariBas and Oceania, Kjerfve *et al.* in prep. and the Arctic Basins (Russia) Gordeev *et al.* in prep.).

3.2 Indicators for coastal change

In East Asia, major indicators for coastal change were identified as increased coastal erosion (change in coastal geomorphology), increased incidence of eutrophication and harmful algal blooms in coastal waters, increased concentration of persistent organic pollutants and trace metals, habitat loss, loss of biodiversity and decreasing biological productivity including decreasing fishery yield, increased incidence of coastal flooding, increased extent of salwater intrusion, and sea-level rise due to land subsidence usually caused by over-pumping of groundwaters.

This workshop report will be used as a basis to carry out research projects on the interaction between the biogeochemical environment and human historical evolution of sites throughout the region.

3.3 Some limitations of this East Asia Basins assessment

Most pressures and corresponding coastal state changes and impacts will significantly alter the coastal environment and ecosystems, their functioning and biodiversity. This has not been included in the matrix table due to the considerable local variability depending on the biogeocoenosis and gaps in quantitative information. Some of the large rivers in the region have not received adequate scientific monitoring and analysis until very recently. Since the history of habitation in East Asia dates back to the appearance of the human race on the Earth and a substantial portion of the world population has lived in a relatively small area, human alteration of the coastal zone has a long history. Recent economic development in the region encourages people to migrate from the interior to the coast, and further accelerates alterations of the coastal zone. Lack of management was identified as one of the drivers in the region, which implies that current legislation is not derived from a sound knowledge of the scientific aspects of the interaction of catchment and coastal zone.

There is an urgent need for a coherent set of case studies using a common framework and tools to give not only better understanding the dynamic interaction of catchments and "their" coastal zone but to upscale the findings to the various catchment-coast system classes on sub-regional scales. This would benefit the overall LOICZ-Basins effort and would advance the state of coastal zone and river catchment management in the East Asian region.

A research initiative under the LOICZ umbrella was identified. The large rivers of the Mekong, Red and Amur rivers lack in basic research to monitor flood and erosion, and contaminants in a standardized manner and a mechanism of transferring research results to legislative processes.

Current work such as the European Basins project "EuroCat" can provide a sound template facilitating a regional approach for East Asia. Formal and/or operational links to ongoing international efforts such as the ICAM (Integrated Coastal Area Management) and COOP (Coastal Ocean Observation Panel) comprising the former C-GOOS (Coastal-Global Ocean Observation System and the Health of the Oceans Initiative) by UNESCO's IOC might provide a good link to global application and users. The Asia Pacific Network for Global Change is expected to play a key role in supporting and disseminating the efforts /results of the work to be continued.

3.4 Tentative design of an "EastAsiaCat" project

Implementation of proposed **"EastAsiaCat"** projects could follow:

- a thematic, across the region approach e.g., driver-oriented across the region; or
- combining the hot spots or classes with most prominent differences between natural and anthropogenic change signals into one project or project cluster.

Advanced modelling and scenario simulation can be tested on sites as a 1-2 year first phase with the potential to become a long-term study. Table 3.2 summarises the "hot spots"/sites with their major driver-pressure-state change characteristics.

Critical loads are still preliminary and need testing and elaboration. Notwithstanding, a set of indicators of environmental changes has to be selected for each potential case study site. Eventually these indicators should be linked to human dimension change as described for the SE Brazil coast (Bidone and Lacerda 2002).

Hydrological watershed alterations have not been considered adequately in this first assessment. Global forcing functions such as climatic change overlap here with anthropogenic drivers from human response to global pressures. Examples are natural disasters such as hurricanes, when immediate effects of flooding may become quite significant, as well as increased efforts to manage freshwater supply by further damming and water abstraction measures.

The list provides examples of key issues and sub-regional river-coast classes in East Asia. The Mekong and Red rivers are good demonstration sites for studying the roles of climate and dams in the coastal flooding and erosion. The Pearl River Delta would be a good site to investigate the influence of agriculture, aquaculture, urbanization and industrialization on eutrophication and pesticides contamination in the receiving coastal waters. The Yellow River is a good example of reduction of river water and sediment discharges by dams affecting coastal erosion and nutrient regime shift in the receiving waters. The Yangtze River may be a good demonstration site for studying interaction between cut-off of river flow and nutrient budgets in the receiving shelf area. The Amur River and Tumen River may need systematic scientific monitoring prior to the impact analysis of drivers. These rivers may become more susceptible to human drivers since they are draining relatively sparsely populated areas.

However, most of the small and medium catchment/coast systems characterizing the East Asia region have not received adequate scientific recognition (notably those located in the southern and northern regions of East Asia). Therefore, there is not yet enough river data to quantitatively assess the coastal issues and natural and anthropogenic activities driven from these catchments – an aspect which should receive priority attention in future East Asia Basins and **EastAsiaCat** research.

Site coordinators will carry further the proposal development and potential funding opportunities on national and international levels.

Table 3.2. Proposed "hot spots"/sites, key drivers and impacts on the coastal zone.

Area location/ sub-region	Major rivers	Major coastal issue	Major driver
1	**Mekong and Red rivers**, Vietnam	Erosion and flooding	Climate and dams
1	**Pearl River**, China	Eutrophication/ pollution	Agriculture/ aquaculture Urbanization/ industrialization
2	**Yellow River**, China	Reduction of freshwater and sediment discharge	Dams
2	**Yangtze River**, China	Cut off of freshwater discharge/ Eutrophication/ecosystem change in the East China Sea	Land Use Change/dams /Western Development
3	**Amur River**, Russia	Contamination	Mining/ urbanization/ agriculture
3	**Tumen River**, North Korea/ China/Russia	Contamination	Future development
1-3	**Small catchments** in the sub-tropical central and northern sub-region	As above	As above but resulting in more pronounced observed coastal impact and dominating wide areas of the coastal zone (e.g., the Vietnamese coast)

Proposed contents for case studies and project structure of "EastAsiaCat"

Aspects to be addressed by the case studies:

1. A scientific review and trend analysis of the changes in freshwater flows, diversions, dams, dimensions of change in the hydrological regimes and consequences on water discharge, sediment transport, sedimentation rates and biogeochemical cycling at the coastal end of the "water continuum".
2. An advanced metadatabase on available information for East Asia catchments indicating the issues, data sources and quality backgrounds.
3. Identification and development of modelling tools and their adaptation as necessary for description of surface material transport, groundwater pathways and retention processes.
4. Derivation of the systemic link between pressures on the river catchments resulting in changing discharge and material flux and observed or projected impacts on the coastal zone. This includes the development of ecological "critical loads/thresholds" to the coastal zone based on investigations into the carrying capacity for waste and soil erosion in the catchments and considering the major drivers for environmental pressures and changes in East Asia. Land-use and cover change information and potential effects on the water continuum are key inputs for these **EastAsiaCat** pilot studies. As critical loads are derived, indicating current and future ecological systems functioning, e.g.,. biodiversity, health and sustained provision of goods and services, they can be fed into the monitoring efforts of COOP and the management initiatives for ICAM in UNESCO's Intergovernmental Oceanographic Commission.
5. The move from the ecological "critical loads" linked to changing C, N, P, sediment and water transport to sectoral activities. Methods used will aim to model that part of ambient material concentrations that can be attributed to economic activity (residual production). In a second step the related socio-economic, i.e., employment and monetary figures will be developed and used in scenario analysis of coastal change and resource provision based on expected trend analysis of sectoral activities in the frame of national, regional and global economies. This step aims to translate coastal systems, their goods and services and change into monetary figures (Costanza *et al.* 1997) thus giving an indication of

performance of policy and management response and related options – the IR of the DPSIR framework (Turner *et al.* 1998, Kremer and Köhn 2000).
6. Up-scaling of information to the other sites identified for comparison on a regional scale.

Structure and Organisation

To make the **East Asia Cat** project and its sub-elements manageable, it will be divided into workpackages. Because not all case studies will have all the necessary expertise, each workpackage will have a scientific coordinator with responsibility for contents and deliverables, and who will initiate relevant capacity-building. At case study level, the site manager will take responsibility for the regional workpackages. The workpackage coordinators and the site managers constitute the management team (Figure 3.1.)

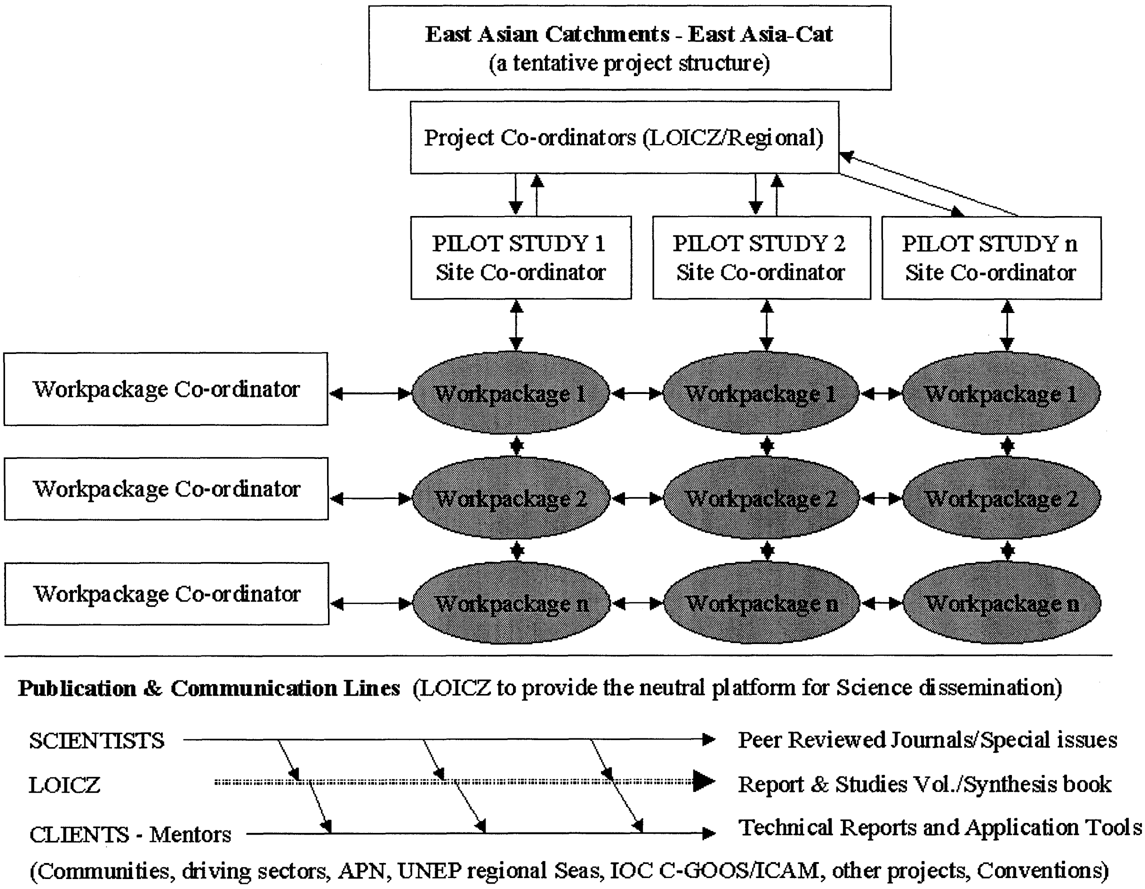


Figure 3.1. Tentative project and task structure for EastAsiaCat and potential pilot studies.

For effective integrated modelling and forecasting, a close integration of the tasks and interaction between the work packages is needed. Figure 3.2 shows an example for this interaction as applied in the **EuroCat** project (see: http://www.iia-cnr.unical.it/EUROCAT/project.htm).

The project database will assist in the development of site-based macro-economic analysis of the impacts of the catchment economy on the coastal zone economy. Scenarios representing various forcing conditions will provide information on biogeochemical changes and key questions in the realm of coastal management, addressing issues such as:

- scaling of coastal change issues resulting from land-based fluxes and efforts for mitigation, i.e. specified land-use practices;
- technical and economic feasibility of modified land-use practices;
- economic instruments applicable for enforcement of improved changes in land-use;

- types of public education and community participation needed to bring about appropriate changes (management response);
- institutional dimensions (national or river basin authorities) needed to formulate and achieve the desired changes.

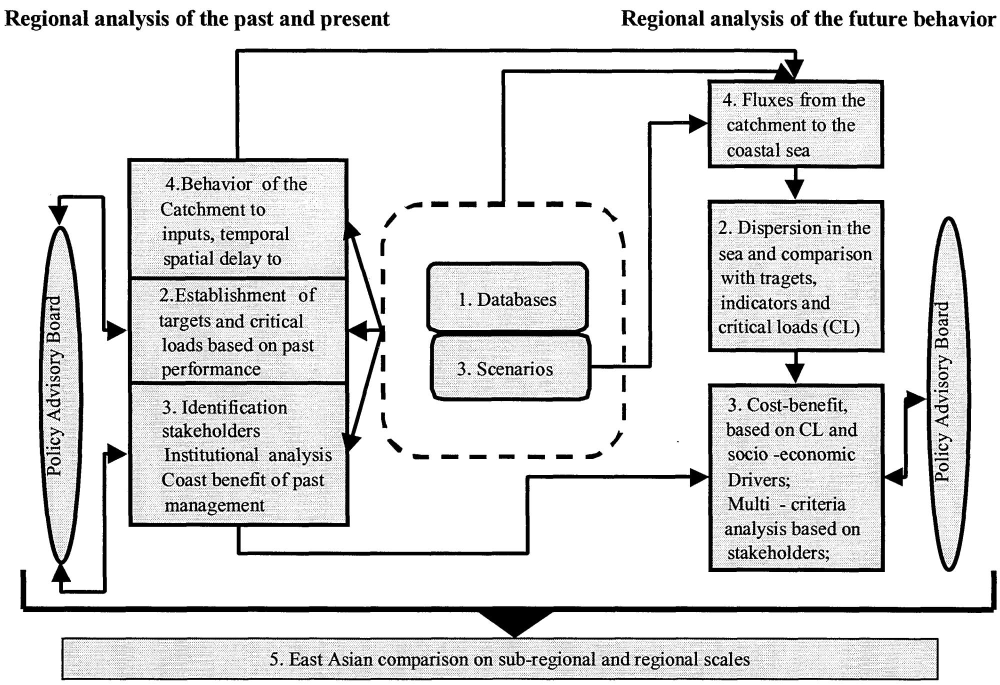


Figure 3.2. A tentative East Asia Cat workplan.

In the first phase of the project, most of the effort will go into establishing databases (WP 1) for the catchment and coastal seas (monitoring data, geographical and socio-economic database). A geographical information system is the basis for the presentation of all of the spatial data and the results. This will draw on data and information provided through existing regional networks and regional projects.

WP 2 will describe impacts in the coastal zone and derive (based on existing data and readily available models) indicators and critical thresholds for East Asia. Existing natural and social science models and tools will be combined to make an instrument suitable for carrying out the regional scenarios.

WP 3 deals explicitly with the development of plausible scenarios of future change. These scenarios will be based on readily available global scenarios but downscaled to the East Asia and then to the site studies and the sub-regions they represent. The socio-economic analysis of the scenarios and present functioning of the coastal zone can draw on experiences (as appropriate) from related global activities carried out in the LOICZ framework and elsewhere. Methodologies applied in the **EuroCat** project, such as the decision support software package DEFINITE, could prove valuable for the implementation of **EastAsiaCat**. The package can assist decision-making with the help of cost-benefit and multi-criteria analyses, the latter allowing the inclusion of costs and benefits which cannot be expressed in monetary terms (see http://www.vu.nl/ivm/ for more detail).

Table 3.4. Outline of workpackages.

Number	Description
1	Databases and tools
2	Impacts, indicators and critical loads
3	Scenarios and response/management options
4	Past, present and future changes in catchment fluxes
5	Integration at the continental level

Catchment fluxes modelling will utilise models addressing point and diffuse sources, groundwater transport and land cover. Existing models such as the German MONERIS or Elbe-model (Behrendt *et al.* 2000; Kunkel and Wendland 1999) and the Mississippi River Model (Rabalais 2002) can be evaluated and adapted to East Asian needs.

In the second phase, the databases and modelling tools will be used to analyse past and present behaviour of the systems. Trend data will assess historical influence on fluxes within the drainage basin of, for example, land-use change, water regulation management, industrial development and population. The temporal and spatial delay in the response of the coastal sea to these changes at the catchment level (regulations and socio-economic) will be evaluated and incorporated in the modelling tools. WP 5 will deal with integrating the results of the individual studies to the East Asian level.

A Policy Advisory Board will be involved in stakeholder identification, institutional analysis and cost-benefit analysis of past measures. Dissemination of scientific findings to various target groups will be a key objective of the board.

Products of EastAsiaCat

The project will not only provide a better understanding of the functioning and change of East Asian coastal systems under natural and human forcing based on an integrative coupling of biogeochemistry and socio economic sciences but also address scenarios and future developments. It sets up a framework of analysis for coastal zone managers and will continue to contribute on regional scales to the overall global LOICZ assessment and synthesis effort. Products will include:

- Catchment case studies in peer-reviewed articles;
- Regional synthesis for evaluation in the global LOICZ network now and under the future IGBP II (with potential input into the joint water project under the Earth System Science Partnership of IGBP, IHDP, WCRP and DIVERSITAS);
- Protocols for integrated assessment, modelling and forecasting for dissemination in training workshops; and
- A platform for participation and client involvement in the form of a Policy Advisory Board (PAB - see **EuroCat** web-page for detail). It will extract information from the project for management purposes, and be actively involved in workpackages 2, 4 and 6. Members of the PAB, comprising local users and stakeholders will disseminate relevant findings of the project.

Contribution from LOICZ

The global LOICZ project under IGBP II will continue to develop and apply tools for assessment, analysis and modelling on various levels. Some of these instruments as well as experiences from other projects may suit the needs of **EastAsiaCat**. Of importance are:

- Budget-models of C, N, P cycling and budgeting tools in the coastal sea (the LOICZ approach, where appropriate; see http://data.ecology.su.se/MNODE/ for further information);
- Tools for integrated modelling to be drawn from the SARCS/WOTRO/LOICZ project in South East Asia (Input/Output and Rapid Assessment modelling (Talaue-McManus *et al.* 2001) – aimed to

determine the residual production of material-fluxes by human activities in biogeochemical, economic and social terms;

- Typology and upscaling tools enabling similarity/dissimilarity analysis, clustering and upscaling of catchment–coastal sea systems using the driver, pressure and state settings to deliver answers to scientists and users;
- Links and synergies with the UN conventions (Biodiversity, Climate Change) and other projects dealing with assessment of environmental change and water such as COOP, the Millennium Ecosystem Assessment, WWAP, GIWA (UNEP/GEF) and regional efforts as appropriate.
- Links to the Global Programme of Action (GPA) and the Asia Pacific Network (APN), as key mechanisms fostering the transfer of the scientific work to the levels of management and political response on global and regional scales;
- A platform for global exchange and comparison of results, publication and science dissemination for the scientific networks involved in LOICZ-Basins and other activities. In addition a neutral forum is provided, enabling a continuous engagement with users as integral part of the studies (this includes intergovernmental bodies such as UNESCO's IOC, private sectors and local communities). The goal is to facilitate joint ownership of issues and actions taken.

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5. CONTRIBUTED PAPERS

5.1. Accumulation of fine-grained sediment and organic carbon in a small tidal basin: Yuehu, Shandong Peninsula, China

Shu Gao and Jian-jun Jia

<u>Extended abstract</u>

The Yuehu (meaning "Moon Lake"), located at the eastern tip of the Shandong Peninsula, is a lagoon that forms the tidal basin of an inlet system, with a total area of 4.94 km^2 and an intertidal area of 1.57 km^2. Five small rivers discharge seasonally into the lagoon; the catchment basin, 15.2 km^2 in area, is characterized by low hills consisting of Cretaceous igneous rocks and sand stones. An entrance channel 132 m wide connects the lagoon with the open sea. The tides are irregularly semidiurnal in character, with a range of 1.15 m on springs and 0.64 m on neaps (0.91 m on average), measured at the entrance to the lagoon. The water depth is small (mostly shallower than 1.5 m), with the mean water level being 0.34 m higher in summer than in winter in response to monsoon climate.

Human activities are intense in this area. The catchment basin is fully cultivated for crops (mainly wheat, maize, peanuts and sweet potatoes). Further, there have been artificial modifications to the lagoon. In 1979, the entrance was sealed artificially, in an attempt to enhance the production of an edible sea cucumber *Stichopus japonicus* Selenka. After the closure, water exchange between the basin and the open sea became extremely slow and the sea cucumber production decreased rapidly. Thus, in 1982, the dam was removed in an (unsuccessful) attempt to restore the environment. In 1986, 0.4 km^2 of the intertidal area was reclaimed for shrimp farming. Since the early 1990s, sand has been extracted from the beach near the inlet entrance. A quay was built at the entrance in 1999. Currently, the shrimp ponds and the base of the old dam are being cleared to improve the ecosystem.

In the present study, we intend to:
(1) identify the accumulation patterns of fine-grained sediment and organic carbon within the lagoon;
(2) examine the impact of human-induced processes on the basin environment; and
(3) consider the implications on the regional patters of organic carbon burial.

For these investigations, some 130 surficial sediment samples and 9 short cores were collected from the tidal basin. In the laboratory, grain size analysis was carried out using a Cilas 940L laser particle sizer, for the surficial sediment samples. The contents of sand, silt and clay fractions were determined, and grain size parameters (i.e., mean, sorting coefficient, skewness and kurtosis) were calculated using a moment method. Sub-samples were taken for every 20 mm of the core. For the sub-samples, water content, grain size distributions and organic carbon content were analyzed. The content of organic carbon (for dried sediment, in terms of mass) was measured using a Perkin-Elmer 240C Elemental Analyzer. Finally, the age of the mud deposit was determined by ^{210}Pb dating. On the basis of these analyses, vertical fluxes of fine-grained sediment and organic carbon as time-series were calculated.

The results show that the tidal basin is largely covered with fine-grained sediments; mud and sandy mud occupy majority of the lagoon area. The water content (ratio of water mass to sediment mass) ranges between 1.07 and 1.31 throughout the short core, with the bulk density and dry specific density of the sediment being 700-1430 kg m^{-3} and 590-690 kg m^{-3}, respectively. Mean grain size is 7-8 φ, with two vaguely-defined clay content maxima occurring at 0-0.5 m and 1.0-1.3 m beneath the bed. The content of organic carbon ranges between 1.85% and 3.42%, with an average of 2.70%. Once again, two maxima occur within the core, at 0.05-0.5 m and 1.0-1.15 m beneath the bed, respectively; they are associated with a relatively high percentages of clay constituent of the sediment. ^{210}Pb dating indicates that the average deposition rate is 18.2 mm yr^{-1}, equivalent to a vertical flux of 11.73 kg m^{-2} yr^{-1}. The corresponding mean burial rate for organic carbon is 0.34 kg m^{-2} yr^{-1}.

Rapid basin filling of the Yuehu may have been caused by two anthropogenic processes. Firstly, the artificial closure of the entrance and subsequent reclamation of the intertidal areas intensified siltation and hampered water exchange. Secondly, soil erosion has intensified during the past 50 years. A quantitative evaluation of these two factors would involve the determination of the material balance among the total sediment volume deposited in the lagoon, the sediment transported into the basin through the entrance channel, locally generated material, and the supply from the land and atmosphere. Assuming that the deposition rate obtained from the short core is applicable to an area of 2.0 km^2, and using a vertical sediment flux of 11.7 kg m^{-2} yr^{-1}, the net quantity of sediment deposited will be of the order of 2.3×10^4 t yr^{-1}. According to measurements of tidal currents and suspended sediment concentrations within the entrance channel for four tidal cycles, net input from the sea towards the lagoon would be of the order of 5×10^3 t yr^{-1}. In this region, the supply from the atmosphere (dust or aerosol) can result in a deposition rate of 0.05 mm yr^{-1} on average. Further, since the average organic carbon content is smaller than 3%, the locally produced material is limited in quantity. If the remainder amount of material (around 1.8×10^4 t yr^{-1}) is from the catchment basin, then a denudation rate of 1200 t km^{-2} yr^{-1}, for fined-grained material alone, would be required. This value is much higher than those under natural processes.

An implication of the study lies in the role played by the coastal mud areas in shallow sea carbon burial patterns. Numerous small sedimentary basins (in the form of coastal bays, estuaries and tidal inlets) are distributed along the shoreline of the Bohai and Yellow Seas in northern China. Thus, if the average vertical flux of organic carbon, i.e. 0.34 kg m^{-2} yr^{-1}, for the Yuehu is appropriate for 2000 km^2 of the region, then the burial rate of particulate organic carbon of the region will be 6.8×10^5 t yr^{-1}. Such a quantity is of the same order of magnitude as that for the adjacent continental shelves. On the continental shelves of the Yellow and Bohai Seas, mud deposits cover an area of around 1.0×10^5 km^2, the average deposition rate 1.5 mm yr^{-1}, and the content of particulate organic carbon 0.8%. Therefore, the total amount of particulate organic carbon burial is 7.6×10^5 t yr^{-1}. Such an observation indicates that for carbon budget analysis, coastal embayments with relatively small areas are actually as important as the shelf areas. This situation must be taken into account in the analysis of continental margin nutrient budgets.

Key Words: Catchment basin, sedimentation, carbon cycling, coastal embayment, eastern China coast.

5.2. Nitrogen budgeting in China and its major river valleys

G.X. Xing and Z.L. Zhu

Abstract
In the China watershed, anthropogenic reactive nitrogen has far exceeded natural terrestrial bio-fixed nitrogen, and human activities have significantly altered the nitrogen cycle. In 1995 in China the total amount of anthropogenic reactive N reached 31.2 Tg (10^{12} g) with 22.2 Tg coming from synthetic fertilizers and 4.18 Tg from NO_x emissions from fossil fuel combustion, while the input of recycled N mainly from human and animal excrement amounted to 30.5 Tg, reflecting the intensity of human activity. The sink of N includes N in the harvested crop, denitrification and storage in agricultural soils, transport into waterbodies and volatilization of NH_3. The N outputted and stored in the soil reached 48-53 Tg. Of this amount, 14 Tg was stored in harvested crops, 12 Tg in agricultural soils, 11 Tg was transported into waterbodies, 5-10 Tg was denitrified in the soils and a limited amount was exported through food/feed.
The Changjiang River, Huanghe River and Zhujiang River are the three major rivers in China that flow into the Pacific Ocean. The N budgets for these river basins and for China are presented here.

Key words: analysis and estimation China watershed, major river valley, nitrogen budgeting,

Introduction

Human activity has markedly altered cycling of nitrogen (N) in nature, with anthropogenic reactive N far exceeding the bio-fixed N in amount in the natural terrestrial ecosystem (Galloway *et al.* 1995). As a result, emission of N_2O, NO_y and NH_x intensifies during biogeochemical N cycling. For instance, N_2O, a long-lived greenhouse gas and a participant in the atmospheric photochemical reaction that leads to depletion of stratospheric ozone, has been increasing drastically since the pre-industrial era. Increasing application of synthetic N fertilizers and other agricultural activities contributes 6.30 Tg N yr^{-1} of N_2O (IPCC 1996; Mosier *et al.* 1998). The amount of NO_3^- transported from land to water has also increased, rendering a negative impact on water quality and aquatic ecosystem processes. As a result, eutrophication of water bodies and red tides in lakes and estuaries occur frequently in China.

NO_x emitted from fossil fuel combustion is a not only a second source of N_2O, but also a major cause of acid rain, which affects adversely forest and aquatic ecosystem process, corrodes buildings and degrades soil quality. The increase in anthropogenic N has significantly disturbed the natural biogeochemical N-cycling on a global scale.

China is the second biggest country on the Eurasian Continent, with a terrestrial area of 9.6×10^6 km^2, accounting for 19% of the continent and the biggest watershed on the west Pacific Ocean. China has the largest population in the world. To meet the food and fiber demands of the 1.2 billion people, application of synthetic N fertilizers has been increasing drastically, reaching 22.20 Tg N in 1995 (China Agricultural Yearbook 1980–1996), about one fourth of the world's total. Moreover, as China is still a developing country, coal remains the chief energy source. In 1995, China consumed approximately 1.4×10^9 tonnes of coal, accounting for 74.6% of the total energy materials used (China Statistical Yearbook 1996). Combustion of coal generates and emits large amounts of NO_x into the atmosphere, some of which later returns to the earth through dry and wet deposition and enters the N cycle in the terrestrial and hydrological ecosystems.

Estimates have been made of N_2O emission, NH_3 volatilization and NO_3^- transport from cropland (Xing and Zhu 1997; Xing 1998; Xing and Yan 1999; Xing and Zhu 2000), NO_x emission from fossil fuel combustion (Wang *et al.* 1996), anthropogenic NH_3 volatilization (Wang *et al.* 1997), production and emission of anthropogenic reactive N (Galloway *et al.* 1996) and N input to estuaries from the Changjiang, Huanghe and Zhujiang Rivers (Duan *et al.* 2000), but the integrated effects of human activities on N cycling in the China watershed are less well-documented (Xing and Zhu 2000).

The Changjiang, Huanghe and Zhujiang rivers, the three major rivers in this watershed, are located in different climatic zones in China. The middle and lower reaches of the three rivers, along the western coast of the Pacific Ocean, are the most developed areas in China, and bear the strongest impact of human activities. However, little work has been done to estimate nitrogen budgets on a valley scale in China. This paper is a first analysis and estimate of nitrogen input, output and storage in the Changjiang, Huanghe and Zhujiang River valleys.

The average total runoff in China is 27.15×10^{11} $m^3\,yr^{-1}$ (Wu 1998). Rivers cover an area of 6.12×10^6 km^2, accounting for 63.8% of the total terrestrial part of China, of which the rivers flowing into the Pacific drain 5.64×10^6 km^2, or 56.7% of the total. The Changjiang, Huanghe and Zhujiang Rivers are the three major rivers (Figure 1), together draining an area of 3.01×10^6 km^2, about 31.1% of the total (Ren *et al.* 1980), with a total runoff of 13.8×10^{11} $m^3\,yr^{-1}$, about 51.1% of the total.

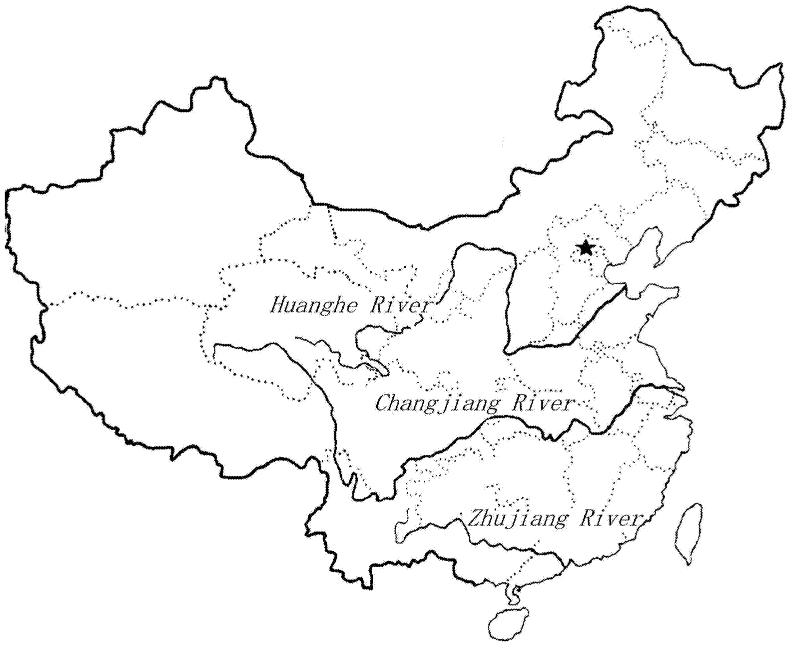

Figure 1. Changjiang, Huanghe and Zhujiang rivers, China.

Basic data and valley characters

Some basic data of the China watershed and the Changjiang, Huanghe and Zhujiang River valleys are listed in Tables 1–4 including area of the river valleys, length and mean flow of the rivers, total amount of runoffs, population and density, land area, area of cultivated land, consumption of chemical N fertilizers; cultivation area of crops; and size of livestock.

The Changjiang River, zigzagging eastwards between 24°-30° N, is the largest river in China, with a basin area of 1.81×10^6 km^2. The river is 6.38×10^3 km long and flows through 18 provinces, metropolises and autonomous regions: Tibet, Qinghai, Yunnan, Sichuan, Guizhou, Hubei, Hunan, Jiangxi, Anhui, Jiangsu, Shanghai, Shaanxi, Henan, Gansu, Zhejiang, Fujian, Guangxi and Guangdong. Its middle and lower reaches stretch from east to west through the subtropics where annual precipitation averages 1.05×10^3 mm. The average annual runoff in the Changjiang River valley is 9.79×10^{11} m^3, more than one-third of the total in China (Table 1). About one-fourth of the country's cultivated land lies within this valley. Of the 2.41×10^7 ha, 1.27×10^7 ha is paddy and 1.14×10^7 ha upland (Table 2).

The Huanghe River, the second largest river, winds between 32.5°-41.7° N, flowing 5.46×10^3 km to the Pacific. It passes through eight provinces and autonomous regions: Qinghai, Gansu, Ningxia, Inner Mongolia, Shaanxi, Shanxi, Henan and Shandong, with a basin area of 0.75×10^6 km^2, mostly arid and semi-arid regions, where the annual precipitation is 0.49×10^3mm. The average annual runoff in the valley is only

0.57×10^{11} m^3, the lowest among the three river valleys (Table 1). The Huanghe River valley has a total of 0.86×10^7 ha of cultivated land, of which 0.029×10^7 ha are paddy fields and 0.84×10^7 ha uplands (Table 2), constituting 9.1% of the total in China.

The Zhujiang River, the fourth largest river, is 2.2×10^3 km long, flows through six provinces and autonomous regions: Guangxi, Guangdong, Yunnan, Guizhou, Hunan and Jiangxi, and has a basin area of 0.45×10^6 km^2 in the southern subtropics between 20°-26° N. The river valley enjoys a humid climate with an annual rainfall of 1.44×10^3 mm. Its annual runoff reaches 3.49×10^{11} m^3, almost half of that for the Changjiang River valley and over six times as much as the Huanghe River valley (Table 1). The cultivated land in the valley consists of 0.31×10^7 ha of paddy fields and 0.18×10^7 ha of uplands, totalling 0.49×10^7 ha (Table 2), or about 5.1% of the whole country. The proportion of paddy fields is much higher in the Zhujiang River valley than in the Changjiang River or the Huanghe River valleys.

Table 1. Hydrological data in the China watershed and the Changjiang, Huanghe and Zhujiang River valleys (Ren *et al.* 1980; Wu 1998; Cui 1999).

Country and river	Drainage area	River length	Annual precipitation	Average flow	Total runoff
	10^6 km^2	10^3km	10^3 mm yr^{-1}	10^3 m^3 s^{-1}	10^{11} m^3 yr^{-1}
China	9.6		0.63		27.15
Changjing	1.81	6.38	1.05	31.06	9.79
Huanghe	0.75	5.46	0.49	1.82	0.57
Zhujiang	0.45	2.20	1.44	11.07	3.49

Table 2. Cultivated land area, consumption of chemical N fertilizers in the China watershed and the Changjiang, Huanghe and Zhujiang River valleys*.

Country and river	Cultivated area (10^7 ha)			Chemical fertilizer-N consumption (Tg N)		
	Upland	Paddy field	Total area	Upland	Paddy field	Total amount
China	7.01	2.49	9.50	17.2	5	22.2
Changjing	1.14	1.27	2.41	3.18	4.12	7.30
Huanghe	0.84	0.029	0.86	1.71	0.07	1.78
Zhujiang	0.18	0.31	0.49	0.51	0.96	1.47

* Calculated on the basis of data from the China Agricultural Yearbook (1996)

Table 3. Population and population density in the China watershed and the Changjiang, Huanghe and Zhujiang River valleys*.

Country and river	Population (10^8)			Population density
	Rural area	City	Total	Individuals per km^2
China	9.02	2.82	11.84	123
Changjing	3.23	0.86	4.09	226
Huanghe	0.57	0.19	0.76	101
Zhujiang	0.76	0.21	0.97	215

* data from the China Agricultural Yearbook (1996)

Table 4. size of livestock in the China watershed and the Changjiang, Huanghe and Zhujiang River valleys*.

Country and river	Number of domesticated animals (10^4 head)					
	Cattle	Milking cows	Horses and other animals	Sheep	Pigs	Poultry
China	12789	417	7656	27695	44169	410858
Changjing	3868	37	302	3924	19464	99447
Huanghe	1110	34	291	3640	2364	37156
Zhujiang	1237	4.5	66	221	4479	32025

* data from the China Agricultural Yearbook (1996)

Methods

Computation of the basic data of the valleys

The basic data used in computing N inputs and outputs in the Changjiang, Huanghe and Zhujiang Rivers valleys were gathered from the 1996 Statistical Yearbook and 1996 Agricultural Yearbook of the related provinces, metropolises and autonomous regions, which, however, were usually compiled on the basis of an administrative region, a province, a metropolis or an autonomous region, rather than a river valley. In order to calculate N budgets of the valleys, the area of the part that the river flows through and its percentage of the total land area of each region was first calculated. Based on the percentage, basic data such as cultivated land area, sown area, population, size of livestock, consumption of chemical N fertilizers, consumption of fossil fuel and area of major crops in the region were calculated. The percentage of river valley within each province for the area of that province where the corresponding river passes was obtained from Zhang (1986), Yi (1957), Xi *et al.* (1994), the Geological Department of Zhengzhou Normal College (1959), the Research Committee of China Natural Resources (1992) and Sun (1959).

Sources of N input

The N inputs of the China watershed and the Changjiang, Huanghe and Zhujiang River valleys can be sorted into two groups, anthropogenic reactive N and recycled N. Sources of the former include application of synthetic fertilizer N, NO_x emission from combusting fossil fuel, symbiotic N fixation by leguminous crops, N-fixation by azotobacteria in farmlands and N imported with food/feed. In calculating N input to the three river valleys, the imported portion was not taken into account. Sources of the recycled N include excrements from humans and animals, atmospheric wet deposition, crop residues left in the farmland as manure and NO_x emission from burning of crop residues in the fields or in kitchens. Atmospheric dry deposition was not included.

Output and *storage of N*

N output was calculated including the following factors: N in the harvested crops and N storage in the farmlands, denitrification of soil N in the fields, NH_3 volatilization, NO_3^- transport into waterbodies and N exported with food/feed. In calculating N fluxes to the waterbodies, according to Howarth *et al.* (1996), the anthropogenic reactive N and that of human wastes were estimated separately. The computation of the N flux from the three river valleys did not include N exported with food/feed.

NO_x emission from combusting fossil fuel

Because of the huge variety of fossil fuels and the great difference in conversion factors used for calculating NO_x emission of the same kind of fuels in different industries (Wang *et al.* 1996), the consumption of the fuels by different industries in China and the Changjiang, Huanghe and Zhujiang River valleys were worked out separately on a kind-by-kind basis. The NO_x fluxes from combustion of coal, coke, crude petroleum, petrol, diesel oil, kerosene, residual oil, liquefied gas and natural gas consumed in different industries were calculated and summed up separately in three categories: coal, petroleum and natural gas. The NO_x flux in China in 1995 from the consumption of each of coal, petroleum and natural gas was obtained individually.

Storage and *denitrification*
Chemical N differs from organic N in storage rate, denitrification rate in soil and between paddy fields and uplands, so N storage from chemical fertilizers and organic manure was calculated separately in paddy fields and uplands. However, N loss through denitrification of organic manure N was calculated regardless of whether paddy fields or uplands.

Atmospheric deposition
N input through atmospheric wet deposition to the Changjiang River and Zhujiang River valleys in South China was calculated separately from that to the Huanghe River valley in North China, because NO_x and NH_3 concentrations in the atmospheric wet deposition show significant zonal difference between north and south.

Conversion coefficients
The calculations of the N budgets in the China watershed and the Changjiang, Huanghe and Zhujiang River valleys were based on the same conversion coefficients except for that for N in atmospheric wet deposition in the three valleys.

Results and Discussion

Input N

N input in the China watershed

Synthetic N fertilizers: application of synthetic N fertilizers is the largest N source in the China watershed, contributing 22.2 Tg in 1995. Before 1950, the consumption of synthetic N fertilizers was limited - only 6×10^{-3} Tg in 1949, about 0.03% of that in 1995. It increased by 3.7×10^{3} times during the 46 years from 1949 to 1995 (Figure 2).

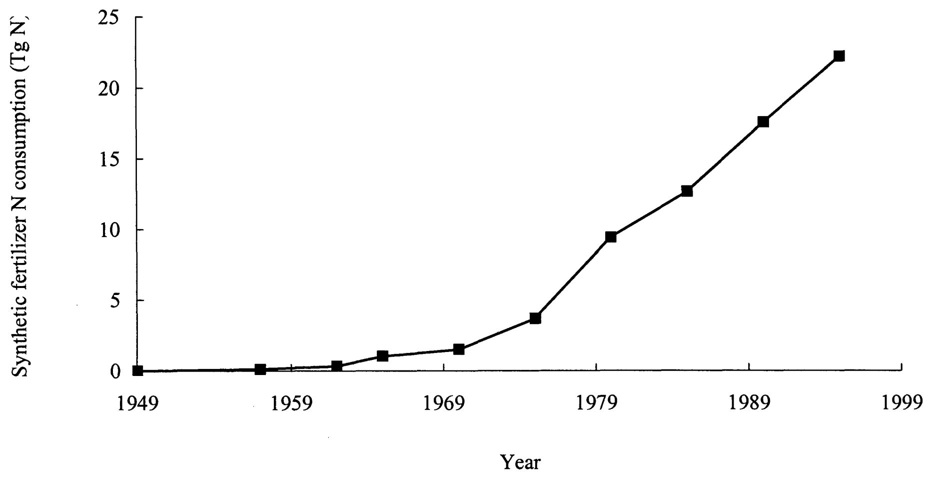

Figure 2. Consumption of synthetic N fertilizers in China from 1949 to 1995.

NO_x emission from combusting fossil fuel: with the development of industry and agriculture in China, the consumption of fossil fuel has been increasing drastically. Based on the conversion factors Wang *et al.* (1996) suggested for calculating NO_x emitted from combustion of different fossil fuels, the NO_x flux in China was calculated on a year-by-year basis (Figure 3). In 1995, 4.18 Tg N was emitted into the atmosphere in the form of NO_x from combusting fossil fuel in China (Table 5). Coal was clearly the biggest contributor to NO_x fluxes in 1995, responsible for 83% of the total..

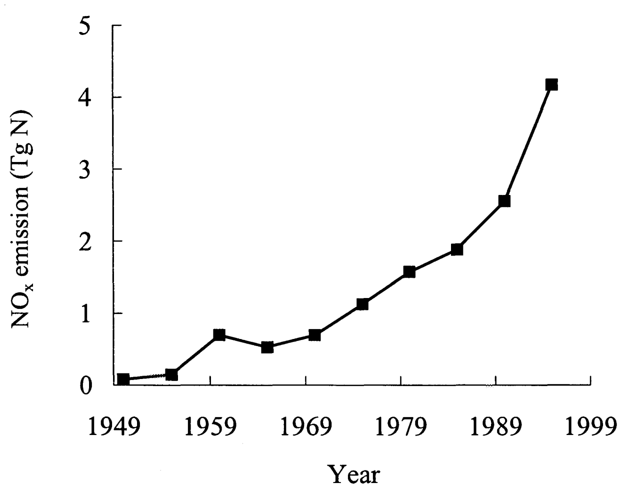

Figure 3. Increasing trend of NO_x emission from combustion of fossil fuels in China.

Table 5. NO_x emission from fossil fuel combustion in 1995 in China.

Type of fossil fuel	NO_x emission (Tg N)	Percentage of total
Coal (including coking)	3.47	83.0
Petrol (including refining)	0.70	16.8
Natural gas	0.01	0.2
Total	4.18	100

Symbiotic N fixation by leguminous crops: In reckoning symbiotic N fixation by leguminous crops in China, only soybean, peanut, pulses and also leguminous green manure crops were taken into account. Based on the data cited from the China Agricultural Yearbooks of 1980, 1981. 1986, 1991 and 1996, and the conversion factors suggested by Zhu (1997), the symbiotic N fixation by leguminous crops during the period from 1949 to 1995 was cacluated and is shown in Figure 4. There is an increasing trend from 1949 to 1976 and then a decline from 1976 to 1980 due to population pressure leading to displacement of green manure with grain crops. The gap in N supply was filled by chemical N fertilizers, which rapidly increased in application rate. Fig. 4 also shows that the symbiotic N fixation by leguminous crops began to turn upward after 1980 due to expansion of the production of soybean, peanut and pulses. In 1995, the symbiotic N fixation by leguminous crops reached 2.16 Tg N in China (Table 6).

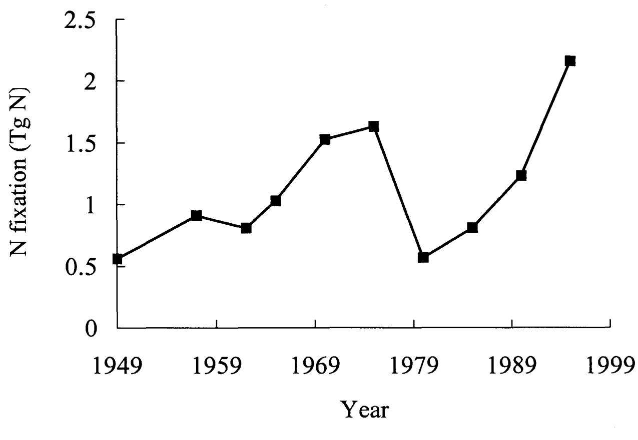

Figure 4. Change in the N fixation by legumes.

Non-symbiotic N fixation: paddy fields account for 26% of total cultivated land in China and one-fifth of the world's total paddy field area. N-fixation in the paddy field is higher than in the upland. Thus, in calculating N input, non-symbiotic N-fixation was included as a source. The conversion coefficient used for non-symbiotic N-fixation in the paddy field and upland was 45 kg $N \cdot ha^{-1} \cdot yr^{-1}$ and 15 kg $N \cdot ha^{-1} \cdot yr^{-1}$, respectively (Zhu 1997). Using that conversion coefficient, the data for area of paddy fields and uplands in 1995 were converted into non-symbiotic N-fixation in the farmland, 2.17 Tg N, among which 1.12 Tg in paddy fields and 1.05 Tg in uplands (Table 6).

N import in food/feed: based on the quantities of agricultural and animal products imported from other countries (China Statistical Yearbook 1996) and N contents in different products (China Agricultural Technical and Economic Manual 1983), the 1995 N inputted from food/feed import was estimated to be only 0.52 Tg N (Table 6).

Table 6. Estimated N input in China (1995).

Items	Amount (Tg N)
Anthropogenic reactive N	
Synthetic fertilizer N	22.2
NO_X-N formed during fossil fuel combustion	4.18
N fixation by legumes in agricultural field	2.16
Non-symbiotic N fixation in agricultural field	2.17
Food/feed import	0.52
Subtotal	31
Recycled N	
N from the excretia of domesticated animal and rural population	
N from the excretia of the domesticated animals	13.7
N from the excretia of rural population	3.07
N from excretia of urban population	1.14
N from crop residue used as fertilizers	1.43
NO_X-N formed during the combustion of crop residues	0.12
N from atmospheric wet deposition	
N from NO_x	2.68
N from NH_x	8.28
Subtotal	31
Total	62

Recycled N: human and animal wastes in the rural areas in China are commonly used as manure. Using the conversion coefficient suggested by Xing and Yan (1999), the total amount of the wastes in 1995 was estimated at 18 Tg N, among which 13.7 Tg was from livestock, 3.07 Tg from the rural population and 1.14 Tg from urban residents (Table 6). About 40% of the wastes were used as manure applied into crop fields. About 38% of the crop residues were utilized for the same purpose. The amount of the residues used in this field was estimated to be 1.43 Tg (Table 6). The rest of the crop residues, about 62%, were burnt partly in farm fields and partly in kitchens as cooking fuel. Using the conversion coefficient of 0.35 $gN \cdot kg^{-1}$ dm for estimating NO_x flux from burning crop residues (Delmas *et al.* 1995), the total amount of NO_x generated from burning of crop residues was calculated roughly at 0.12 Tg N in 1995 (Table 6). Reports from 27 year-round monitoring posts scattered all over the country (Wang 1994), from the two similar posts in Shandong Province (Zhang and Liu 1994) and from one in Qinghai province, West China (Yang *et al.* 1991) indicated that the mean values of concentrations of NO_3 and NH_4 in the precipitation were 4.36×10^2 mg N m^{-3} and 1.35×10^3 mg N m^{-3}. Using the data of the mean annual precipitations from 1951 to 1990 in Table 1, we estimated the atmospheric wet deposition N in the early 1990s to be 11 Tg, of which 2.68 Tg was NO_3 and 8.28 Tg NH_4 (Table 5), showing a NO_3:NH_4 ratio of 1:3. Obviously the proportion of NH_4 in the ratio is much higher in China than in other parts of the world (Galloway 1985; Loye-pilot and Morelli 1988; Weijer and Vugts 1990), which might be due to the high proportion of ammonium dicarbonate, about 50%, in chemical fertilizers in China. This type of fertilizer suffers higher NH_3 loss through volatilization than do urea and other types of N fertilizers. Inadequate handling facilities for human and animal wastes also result in higher volatilization of NH_3 from wastes in China.

The fluxes of anthropogenic reactive N and recycling N to the China watershed summarized in Table 6 indicate that the total amount of N fluxes to the China watershed is 62 Tg, of which 31 Tg, about 50%, is anthropogenic reactive N and 31 Tg, about 50%, recycling N.

N input to the Changjiang, Huanghe and Zhujiang River valleys

The input of anthropogenic reactive N to the Changjiang, Huanghe and Zhujiang River valleys was 9.5 Tg, 2.3 Tg and 1.9 Tg, respectively, accounting for 31%, 8% and 6% of the total to the China watershed in 1995. Synthetic chemical N fertilizers were the main source of N input to the valleys and estimated at 7.30 Tg, 1.77 Tg and 1.47 Tg (Table 7), accounting for 77%, 76% and 79% of their corresponding total of anthropogenic reactive N input. The N fluxes from the other sources of anthropogenic reactive N to the valleys are all shown in Table 7.

The flux of recycled N to the Changjiang, Huanghe and Zhujiang Rivers was 9.5 Tg, 2.2 Tg and 2.8 Tg, respectively (Table 7). Human and animal wastes, the predominant source of recycling N in the three valleys, contained 5.32 Tg N, 1.45 Tg N and 1.36 Tg N, respectively, accounting for 56%, 66% and 49% of their corresponding total of recycled N input.

Atmospheric wet deposition N to the Changjiang, Huanghe and Zhujiang river valleys was estimated from two different groups of values, because the concentrations of NO_3 and NH_4 in the precipitation differ between North China and South China (Wang 1994). Integration of the results from studies (Wang 1994; Zhang and Liu 1994; and Yang *et al.* 1991), yielded mean concentrations of 3.35×10^2 mg N m^{-3} NO_3 and 1.42×10^3 mg N m^{-3} NH_4 in precipitation in North China and 5.11×10^2 mg N m^{-3} NO_3 and 1.47×10^3 mg N m^{-3} NH_4 in South China. Since the Huanghe River valley is in North China, the atmospheric wet deposition of NO_3 and NH_4 there was estimated as 0.12 Tg N and 0.52 Tg N, respectively (Table 7). The Changjiang River valley and the Zhujiang River valley are in South China, so their atmospheric wet deposition of NO_3 and NH_4 was determined to be 0.96 Tg N and 2.79 Tg N, and 0.33 Tg N and 0.96 Tg N, respectively (Table 7). The NO_3:NH_4 ratio in the atmospheric wet deposition in the Changjiang, Zhujiang and Huanghe river valleys was 1:3, 1:3 and 1:4, respectively.

Table 7. Estimated N input in the Changjiang, Huanghe and Zhujiang River valleys (1995).

Items	Amount (Tg N)		
	Changjiang	Huanghe	Zhujiang
Anthropogenic and naturally reactive N			
Synthetic fertilizer N	7.30	1.77	1.47
NO_x formed from fossil fuel combustion	0.91	0.28	0.16
N fixation by legumes in agricultural field	0.56	0.15	0.10
Non-symbiotic N fixation in agricultural field	0.74	0.14	0.16
Subtotal	9.5	2.3	1.9
Recycling N			
Excreta N of human and raised animals			
N from the excrements of raised animals	3.93	1.24	1.03
N from the excrements of the rural population	1.10	0.14	0.26
N from the excrements of the urban population	0.29	0.07	0.07
Subtotal	5.32	1.45	1.36
N from crop residue used as fertilizer	0.43	0.14	0.14
NO_X-N formed from crop residue combustion	0.04	0.011	0.01
Atmospheric wet deposition N			
NO_x-N	0.96	0.12	0.33
NH_x-N	2.79	0.52	0.96
Subtotal	9.5	2.2	2.8
Total	19.0	4.6	4.7

N output and storage

N output and storage in the China watershed

N in the harvested crops: Based on the data from the China Agricultural Yearbook (1996) about yields of 30 major agricultural crops (including seven species of vegetables) and the data about N contents in the crops and N distribution ratio between straw (leaves and stems) and grains (edible parts) listed in a number of handbooks (Lu and Shi 1982; China Agricultural Technology and Economy Manual 1983; Pang 1994; Huang *et al.* 1996), the N in the harvested crops was calculated to be 14 Tg, of which 10.5 Tg was grains and edible parts and 3.5 Tg was straws (Table 11).

Denitrification in farmland: rate of N loss through denitrification is higher paddy fields than in uplands, and also depends on the origin: chemical fertilizers or organic manure (Table 8). The data in Table 8 are all based on micro-plot field experiments carried out with chemical fertilizers, green manure, rice straw, pig dung and sheep droppings, all labeled with ^{15}N. In 1995, 5 Tg N of chemical fertilizer was applied to the paddy fields and 17 Tg N to the uplands, and 10 Tg N in organic manure to the farmlands of China. By using the data in Table 8 as conversion coefficients, the N losses through denitrification in 1995 from chemical fertilizers in paddy fields and in uplands and from organic manure in cropland were estimated. The N loss was estimated at 1.65-2.05 Tg N from chemical fertilizers in paddy fields, 2.23-4.99 Tg N from chemical fertilizers in uplands, and 1.03-3.10 Tg N from organic manure in cropland. So the total N loss through denitrification from the farmland reached 5-10 Tg in China in 1995 (Table 11).

Table 8. Conversion factors for N loss through denitrification in agricultural fields of China.

Fertilizer type	Conversion factor	Reference
Synthetic fertilizer N		
Rice paddy fields	33-41%	Zhu (1997)
Uplands	13-29%	Cai *et al.* (1998)
Organic fertilizer N	10-30%	Wen *et al.* 1988; Shi *et al.* 1991; Chen *et al.* 1994; He *et al.* 1994.

N storage in farmland: The N detention rate of chemical N fertilizers varies from paddy fields to uplands. On average, it is higher in the former than in the latter. It also differs from that of organic manure, which has a higher residue rate. Zhu* summarized the results of 142 field and greenhouse experiments with ^{15}N-labeled chemical N fertilizers and ^{15}N-labeled organic manure in different soils (Table 9). Based on the data in Table 9 as conversion factors, the N retention was worked out as 12 Tg N in China in 1995, indicating this was the most important access to sink.

Table 9. Estimated N storage in agricultural soils in China (1995).

N type	Application amount (Tg N)	Storage ratio* (%)	N storage (Tg N)
Synthetic N			
Paddy fields	5.00	20 (12-30)	1.00
Uplands	17.20	27 (11-68)	4.64
Organic N	12.04	49 (27-78)	5.9
Total	34.97		12

* data from Zhu ZL unpublished paper.

N transport to waterbodies: N transport to waterbodies in the China watershed can be divided into two portions: anthropogenic reactive N and human wastes discharged directly into waterbodies. The former includes synthetic chemical N fertilizers, symbiotic N-fixation by leguminous crops and green manure crops, N imported with food and feed, N in atmospheric wet deposition and non-symbiotic N fixation in the cropland, because paddy fields account for 26% of the country's total farmland and non-symbiotic N-fixation in paddy fields is much higher than in the upland. The latter encompasses wastes from urban residents and rural population. In calculation, only 60% of the wastes from rural population were counted because about 40% of the wastes in the rural area are used as manure.

The anthropogenic reactive N transported into waterbodies through leaching and runoff was estimated at 8.20 Tg by using the IPCC (1996) default value, 30% (ranging between 10 and 80%), as the conversion factor, whereas the N in human wastes discharged directly into waterbodies was calculated as 2.7 Tg in China in 1995 assuming that the contribution rate of human wastes to N load in waterbodies was 3.3 kg $N \cdot yr^{-1}$ per person (Meybeck 1989). Thus, the total N transport into waterbodies was 11 Tg. In the calculation, N in atmospheric wet deposition was included, but not that in atmospheric dry deposition. The rural area still had 60% of the animal wastes left unused. It is very hard to estimate how much N was transported into waterbodies from that portion. Consequently, the N transport into waterbodies in China might be underestimated. Nevertheless, China differs from other countries in climate and farming system. Under the significant influence of monsoons in most agricultural regions, rainfall is concentrated in summer and is minimal in winter and spring. Moreover, the major agricultural regions, with a humid and warm climate, can grow crops all year round. In addition, 26% of farmland in China grows rice. Thus, using 30% of the N applied as conversion factor for the calculation of N transport into waterbodies in the China watershed might lead to overestimation. There is much uncertainty in calculating N transport into waterbodies in the China watershed.

NH_3 volatilization: China does not have many varieties of chemical N fertilizers. Urea and ammonium bicarbonate are the two dominant ones, sharing the makeup of chemical N fertilizers in 1995. Since 1995 the latter has declining in proportion in favor of the former. Studies reveal that N loss rate through NH_3 volatilization varies, with ammonium bicarbonate higher than urea and with upland higher than paddy field. Human and animal wastes are another source of NH_3 volatilization. In calculating its N loss through NH_3 volatilization, the IPCC-recommended default value of 0.2 kg N (NH_3 + NO_x) kg^{-1} N in human and animal wastes was used as conversion factor. However, the NO_x content in the wastes is rather limited. NH_3 volatilization from the animal wastes applied to farmland accounted for 20-25% (Schimel *et al.* 1986; Van der Hoek 1994) of the N in the wastes. Based on the conversion factors listed in Table 10, the NH_3 volatilization in the agriculture of China was estimated at 6.1 Tg N, of which 3.35 Tg originated from human and animal wastes (Table 11).

Table 10. NH_3 volatilization conversion coefficient.

Sources	Emission factors (kg N kg^{-1}N)	References
Animal and human excretia N	0.20	IPCC 1996
Synthetic fertilizer N	Upland: 0.08 for urea and 0.10 for NH_4HCO_3	Xing and Zhu 2000
	Paddy field: 0.22 for urea and 0.28 for NH_4HCO_3	

Food/feed exports: although China produces the most agricultural products, the demand of such a big population greatly limits its export of those products. According to the statistical data about the export of agricultural products (China Agricultural Yearbook 1996) and about N contents in these products, the total estimated N exported with food/feed was only 0.11 Tg (Table 11).

Table 11. Estimation of N output and storage in China (1995).

Items	Amount (Tg N)
N in the harvested crops	
N in the grains (edible parts)	10.5
N in the straws	3.5
Subtotal	14
Denitrification	
Synthetic fertilizer N	
Rice fields	1.65-2.05
Uplands	2.23-4.99
Organic fertilizer N	1.03-3.1
Subtotal	5-10
Storage in agricultural land	
Synthetic fertilizer N	
Rice fields	1.0
Uplands	4.6
Organic fertilizer N	5.9
Subtotal	12
N transported into waterbodies	
Anthropogenic reactive N	8.2
Excreta N directly from population in urban and rural areas	2.7
Subtotal	11
NH_3 volatilization	
From chemical fertilizer N	2.71
From excreta of raised animals and humans	3.35
Subtotal	6.1
Food/feed exports	0.11
Total	48-53

From Table 11, it can be inferred that N in the harvested crops and N storage in soils are the largest sinks of input N in the China watershed, followed by N transport into waterbodies, denitrification in agricultural soils and NH_3 volatilization.

N output and storage in the Changjiang, Huanghe and Zhujiang River valleys

The N output and storage in the Changjiang, Huanghe and Zhujiang River valleys was estimated at 16-18 Tg, 3.6-4.1 Tg, and 4.1-4.4 Tg, respectively (Table 12).

Based on the statistical data about the yields of the 30 major agricultural crops on a province-by-province basis in the China Agricultural Yearbook (1996) and the method described in the previous paragraphs, the N in the harvested crops in the Changjiang, Huanghe and Zhujiang River valleys were calculated to be 4.34 Tg N, 1.04 Tg N and 1.07 Tg N, respectively.

Of the output and storage N from the Changjiang, Huanghe and Zhujiang River valleys, 3.51 Tg, 0.95 Tg and 1.16 Tg was stored in soil (Table 12). The calculation used the conversion factors listed in Table 9.

N transport to waterbodies in the Changjiang, Huanghe and Zhujiang River valleys was calculated in the same way as that in the China watershed. It was divided into two parts: anthropogenic reactive N and human wastes discharged direct into waterbodies. The same conversion factors were used, the IPCC (1996) 30% default value for the former and Meybeck (1989) 3.3 kg N yr^{-1} per person for the latter. The total N transported into waterbodies in the Changjiang, Huanghe and Zhujiang River valleys was estimated at 3.79 Tg, 0.83 Tg and 0.84 Tg, respectively (Table 12). Though the acreage of the Zhujiang River valley is only 60% that of the Huanghe River valley, the N transport into waterbodies differs little between them. This is because the Zhujiang River valley is in tropical and subtropical South China and has much higher precipitation and runoff rates than the Huanghe River valley, in the semi-arid temperate North China. Due to the humid and warm climate, the former can have 2-3 croppings a year whereas the latter can only support one cropping and a vast area of grassland. As a result, the per-unit application rate of chemical N fertilizers in the former is much higher than that in the latter. Moreover, the population density of the former is almost twice that of the latter (Table 3).

Based on the information about DIN concentrations in the three rivers and related hydrological data gathered in 1980–1989 from three observation posts located at each of the lower reaches of the rivers, Duan *et al.* (2000) calculated the DIN transported into the estuaries as 0.78 Tg, 0.06 Tg and 0.15 Tg, respectively. Though those results did not include organic N, they are much lower than our results (Table 12), indicating that there is much uncertainty in calculating N transport from the valleys into estuaries, which calls for further studies.

Denitrification of soil N in farmland is another possible sink for N in the Changjiang, Huanghe and Zhujiang river valleys. By using the conversion coefficients listed in Table 6, N loss through denitrification of soil N in farmland in the Changjiang, Huanghe and Zhujiang River valleys was estimated at 2.14-3.73 Tg, 0.34-0.82 Tg and 0.48-0.77 Tg (Table 12), accounting for 18-30%, 13-27% and 16-25%, respectively, of the N output and N storage in the valleys. The percentages of the N loss through denitrification against N output in the Changjiang River valley and the Zhujiang River valley were similar, but higher than in the Huanghe River valley. This is because the former two valleys are the major rice growing regions of China, while the latter has only a limited acreage of paddy fields (Table 2), and because denitrification of soil N is much higher in paddy fields than in uplands.

Calculation of the NH_3 volatilization of synthetic chemical N fertilizers and human and animal wastes in the three valleys, based on the conversion factors listed in Table 10, was estimated at 2.32 Tg, 0.45 Tg and 0.56 Tg, respectively.

Table 12. Estimated N output and N storage in the Changjiang, Huanghe and Zhujiang River valleys (1995).

Items	Amount (Tg N)		
	Changjiang	Huanghe	Zhujiang
N in the harvested crops	4.34	1.04	1.07
Denitrification in agricultural soils			
Synthetic fertilizer N			
Rice fields	1.36-1.69	0.02-0.03	0.32-0.39
Uplands	0.41-0.92	0.22-0.50	0.07-0.10
Organic fertilizer N	0.37-1.12	0.10-0.29	0.09-0.28
Subtotal	2.14-3.73	0.34-0.82	0.48-0.77
Storage in agricultural land			
Synthetic fertilizer N			
Rice fields	0.82	0.012	0.19
Uplands	0.86	0.46	0.14
Organic fertilizer N	1.83	0.48	0.83
Subtotal	3.51	0.95	1.16
N transported into the waterbodies			
Anthropogenic and natural reactive N from input sources	2.87	0.65	0.62
N from the excreta of people in urban and rural areas	0.92	0.18	0.22
Subtotal	3.79	0.83	0.84
NH_3 volatilization			
From chemical fertilizer N	1.32	0.17	0.29
From excretia N of raised animals	1.0	0.28	0.27
Subtotal	2.32	0.45	0.56
Total	16.-18	3.6-4.1	4.1-4.4

Conclusion

In China, with the biggest population in the world, anthropogenic activities have been significantly altering the N biogeochemical cycling in the region with the rapid development of industry and agriculture. The total anthropogenic reactive N was estimated at 31 Tg in 1995, of which 22.2 Tg came from application of synthetic chemical fertilizers, 4.18 Tg from NO_x emission from combusting fossil fuel, 2.16 Tg from N fixation by leguminous crops and 0.52 Tg from food/feed imports. Non-symbiotic N-fixation in farmlands was estimated to be 2.17 Tg. Although N fixation in forests, grasslands, natural wetland and lightning N are not included, it is indubitable that human-created N far exceeds terrestrial biological N fixation. Synthetic chemical N fertilizer is the dominant source of anthropogenic reactive N. NO_x emission from combusting fossil fuel is another major source since China is one of the biggest coal consumers globally.

The amount of recycled N reflects acceleration of the N-cycling as influenced by human activities. The analysis and evaluation of the recycling N in the China watershed shows that this part of N could not be negligible, and totalled 31 Tg in 1995, with 17.9 Tg coming from human and animal wastes.

The total N sink in the China watershed amounted to 48-53 Tg in 1995, with N in the harvested crops and N storage in agricultural soils being the major sinks and amounting to 14 Tg and 12 Tg, respectively. The total N loss through denitrification of soil N was estimated at 5-10 Tg in 1995, and the total N transport into waterbodies at 11 Tg, which was an estimate with much uncertainty.

The N budgeting on the basis of valley show that the N input and N output in the Changjiang, and Zhujiang River valleys, which are the well-developed regions of China, were much higher than that in the Huanghe River valley located in the arid and semi-arid warm temperate zone.

This estimation was performed mainly based on agricultural N recycling and NO_x emission from combusting fossil fuels. The N sources and sinks in forests, grasslands and natural wetlands are not yet integrated into our N budgeting in China. However, from the viewpoint of evaluating the influence of human activities on N cycling, it is reasonable to estimate N input and sinks on the basis of agricultural N cycling.

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5.3 Impacts of inland human activities on coastal seas surrounding China - past, present and future (discharge changes of water, sediment, nutrients and other substances from the Yangtze, Yellow and Pearl River)

Dunxin Hu

Abstract only

The big Chinese rivers such as the Yangtze and Yellow are heavily affected by human activities such as dam construction (number one in the world), fertilization practice (number one in the world), urbanization (one of the fastest in the world), land-use (one of the highest levels in the world) and thus are ideal to study horizontal material fluxes, since the two rivers run zonally crossing mainland of China all the way from the west (originating from mountains) to the east (emptying into the coastal seas). Those riverine material discharges contain rich information about anthropogenic impacts. The Yellow River is an excellent example in terms of anthropogenic impact on water and sediment discharges due to cultivation, diversion, irrigation, dam construction, soil erosion, conservation, water management and so on.

The Yangtze River is a good example of nutrient discharge affected by fertilizer application resulting in deterioration of biological resources and the marine environment, as indicated by eutrophication and red tides in the East China Sea. The Pearl River is another example for anthropogenic impact due to urbanization and rapid economic development in the Pearl River delta area.

For the future, there are a number of things to be considered:

1. Management of water use.

Until two years ago the drying up of the Yellow River had been getting steadily worse (over 200 days in 1997). With good coodination in water use along the whole basin, however, the number of drying up days dramatically decreased during the last two years.

2. Development of central and western parts of China.

A big project on the development of the central and western parts of China has started. The consequences of this project in terms of the riverine material discharge and the marine environment and ecosystem changes need to be taken into account.

3. Diversion of water from the south (Yangtze River) to the north.

The central government announced the project of water diversion from the South (Yangtze) to the North with three diversion lines (east, middle and west lines) will start soon and the first component of the project will be completed in a ten years time. It is estimated that some 60 billion cubic meters of water, about one tenth of the annual water discharge of the Yangtze River, will be diverted annually to the north. What would be the impact of this on riverine material flux, the marine environment and ecosystem?

5.4 The impact of human dimensions on land use changes in the Yangtze River delta in the past 50 years*

Lijie Pu, Guishan Yang and Mengjie Xu

Abstract

China has the largest population of any country on Earth but relatively limited arable land. With the rapid development of industrialization and urbanization in recent years, arable land area has decreased sharply in Yangtze River Delta, which is one of the most developed areas in China. Analysis of the processes and drivers of arable land changes, using the statistics from the past 50 years and the land inventory of the past 5 years, indicates that the arable land has in general decreased in the past 50 years, but at variable rates. There were three periods of peak decrease: 1958 to 1963, around 1985 and around 1993. The drivers are national policy, economic growth and population increase.

Introduction

Land, a basic natural resource, provides the foundation for human survival and development. Under the influences of both human and natural factors, land use and cover change (LUCC) has been one of the eight IGBP core projects (IGBP 1995). As a developing country, China has a cultivation land *per capita* far below the world average. With rapid economic development, the reduction in area of arable lands seems to be an unavoidable trend. In recent years the field of LUCC has been studied for the whole country or several typical regions from different scientific angles such as remote sensing and environment security (see Li 1999; Zhangmin 1999; Gu 1999; Lizia 1997; Zhou and Wang 1999; Shi *et al.* 1999).

With a high population density, the Yangtze Delta has traditionally extensive land use. Rapid economic development since the 1980s has led to changes in land use and in the relationship between land and population due to the decrease in arable lands, typical in today's China.

Our research concentrated on the process and the drivers of the arable land changes within the past 50 years in the Yangtze Delta.

The Yangtze Delta refers to the region including Nanjing, Wuxi, Changzhou, Suzhou, Nantong, Yangzhou, Zhenjiang and Taizhou of Jiangsu Province and Hangzhou, Jiaxing and Huzhou of Zhejiang Province and Shanghai. According to the last land investigation in 1996, the Yangtze Delta has an area of 844.1×10^4 hm^2, accounting for only 0.88% of the whole country. Land area *per capita* is only 0.133 hm^2, which is about 1/6 of the national average level. The region includes 325.3×10^4 hm^2 of cultivated lands, 33.2×10^4 hm^2 of garden, 124.5×10^4 hm^2 of urban paved area (transport corridors, factories, mines and dwellings), 145.1×10^4 hm^2 of grasslands and woodlands, 197.5×10^4 hm^2 of watershed and 18.5×10^4 hm^2 of unused lands.

The basic characteristics of land use

High land reclamation rate and low cultivation land per capita

The Yangtze Delta has a long history of agricultural activities and has one of the highest land use rates. Plains including watershed account for only 55% of the total area. Watershed alone accounts for 23.4% of the total area. The proportion of cultivated lands (38.5%) is about four times the national average level of 9.9% and about three times the worldwide average of 12.2% (Almanac of China Land Resources). Excluding the watershed and the undeveloped lands, the land-use rate exceeds 57%. The Yangtze Delta has a population density 6 times the national level so the land area *per capita* is only 0.05 hm^2, which is about 2/3 of the national level and 1/5 of the worldwide level. With the rapid decrease in arable land, the region's fame as an important food production base is no longer sustained and land prices have skyrocketed which increases production costs and leads to the loss of regional low-cost advantages in competition.

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Intensive land use and high output value

Although its land area accounts for less than 1% of the whole territory and its population about 3%, the Yangtze Delta achieved 13.8% of the national GDP in 1998. According to statistics for 1998, fixed investment *per capita* in the Yangtze Delta amounted to 529.2×10^4 yuan/km^2, which was 18 times the national average. Fertilizer application to cultivated lands amounted to more than 647 kg hm^{-2}, which was about 1.3 times the national average. Intensive land exploitation and high input bring high output. The regional comprehensive output value *per capita* reached 1301×10^4 yuan km^{-2}, which was 17 times the national average of 83×10^4 yuan km^{-2}. The cultivated lands in this region had an average yield of 7272 kg hm^{-2} and an average agricultural output value of 2.6×10^4 yuan km^{-2}, which were 1.4 times and 1.7 times the national average level respectively. Shanghai has the highest fixed investment *per capita* at 104 times the national level and the highest comprehensive output value 70 times the national level (Table 1).

Table 1. Land use intensity and land output in the Yangtze Delta and China (1998).

		Fixed investment *per capita* (10^4 yuan km^{-2})	Fertilizer application *per capita* (kg hm^{-2})	Comprehensive output value *per capita* (10^4 yuan km^{-2})	Output value of cultivated land *per capita* (10^4 yuan km^{-2})	Yield (kg hm^{-2})
The Yangtze Delta	Shanghai	3081.0	647.0	5783.8	3.0	7235.3
	Jiansu part	364.3	618.0	1048.4	2.5	7226.1
	Zhejiang part	236.9	454.7	715.4	3.0	7714.5
	Average	529.2	554.9	1301.1	2.6	7272.4
China		29.6	430.2	82.7	1.5	5394.3

Paved urban areas increases rapidly

High population density, developed economy and rapid urbanization are all factors leading to the fast increase in paved urban areas. The proportion of paved urban areas in the Yangtze Delta (14.8%) is about 1.5 times that in the Beijing-Tianjing-Tangshan Region although both regions have a highly developed economy. In 1985 the proportion of the paved urban areas in China was 2.5% on average. In 1985 the proportion of the area for transport infrastructure was 2.4% in the United Kingdom, 2% in France and 2.8% in Japan (She 1997). In 1996 land transport infrastructure accounted for 2.3% of the total area of the Yangtze Delta. Within the last 10 years more and more croplands have been converted into construction lands. In Suzhou City for example, from 1994 to 1998 the area of built-up land increased by 1.0×10^4 hm^2, which was 1.2% of the newly-added paved urban areas of China for the period. The area of paved urban areas in Suzhou increased at an annual rate of 1.9%, which was 2 times the national average. Among the newly added paved urban areas, factories, mines and dwellings increased by 8711 hm^2 at an annual rate of 2.0% and transport infrastructure increased by 1332 hm^2 at an annual rate of 1.8%.

Rapid decrease in area of arable lands

According to the statistics, from 1980 to 1995 the Yangtze Delta saw a decrease of 24.7×10^4 hm^2 in arable lands, which was about 5.6% of the decreasing arable land area in China. Using the ratio of decreasing arable land area to the total land area per year to indicate the rate of decrease, the Yangtze Delta had a ratio more than 0.20 hm^2 km^{-2} yr during the period, which was 6.7 times the national average of 0.03 hm^2 km^{-2} yr. The cultivation lands in this region decreased at an annual rate of 0.05%, which was twice the national average rate. Among all the counties and cities, 3/5 had an annual decreasing rate exceeding 0.5% and 1/4 had a rate more than 1.0%. Wuxian County and Wujiang County located in the suburbs of Suzhou City had an annual decreasing rate higher than 2% within the past 15 years.

The process of the arable land change

The arable land area of the Yangtze Delta has undergone several fluctuations within the past 50 years. The trend can be divided into four different stages. From 1949 to 1952 the area available for cultivation increased at an annual rate of 1.15%, but from 1953 the land area began to decrease.. The rate of decrease varied, with peaks of decrease in 1958, 1985 and 1993 (see Figure 1).

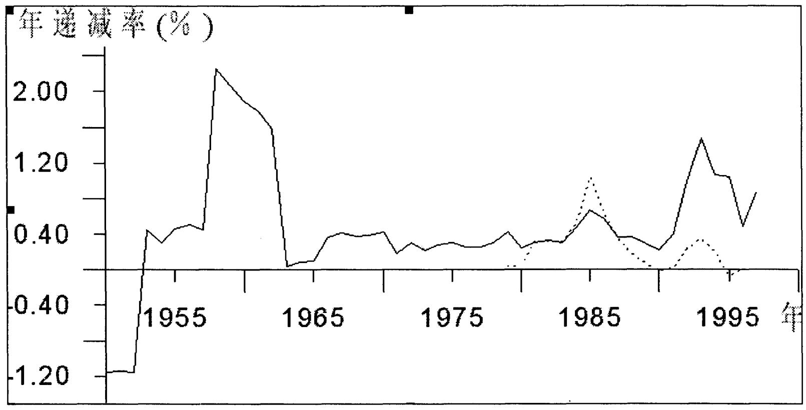

Figure 1. The decrease in arable land use changes in the past 50 years in Yangtze River Delta, in comparison with the China average (dotted line).

The drivers of the land use changes

The main factors influencing the changes of cultivation land area in the Yangtze Delta within the past 50 years are human ones, including national policy, economic growth and population increase.

National policy

Each of the sudden changes of arable land area in the Yangtze Delta can be traced to changes in national policy.

In the first years after liberation the newly-set political system provided incentives for peasants to reclaim their lands, so the cultivated land area increased gradually. The year 1953, the turning point when the increase beacme a decrease, was directly connected with the regional extension of the agricultural co-operation movement and the construction of large-scale agricultural irrigation works. From 1958 to 1962 the Yangtze Delta had its first trough, which was the longest and strongest of the three troughs

In 1984 the Chinese government began to implement the policy of opening to the world. Fourteen coastal cities were open to foreigners and four special economic zones (SEZ) and 14 technical and economic zones (TEZ) were set up. The economy of the Yangtze Delta grew rapidly and the town and village enterprises prospered, which led to the second trough. Because the government focused on the Zhujiang Delta at that time, the second trough was not as distinct as the other two (Yang and Wang 1996).

The Yangtze Delta experienced an unprecedented "TEZ tide" when the government began to carry out the "Yanjiang strategy" to develop the areas along the Yangtze River. The economy developed quickly at the cost of large area of cultivated lands. Arable lands were converted into all kinds of TEZs. TEZs grew from 17 in 1991 to 74 at the end of 1997 in spite of efforts to control the scale. Suzhou alone had 11 such zones with the total area of 3.2×10^4 hm^2, which were about four times the area approved by government. That inevitably induced the third trough.

Economic growth

Arable lands being converted into non-agricultural uses became common in the highly developed regions in China. Generally with the further improvement of techniques and industries the economy will gradually develop more intensively and the pressures on resources are relieved. Although one of the developed regions, the Yangtze Delta is still developing in a relatively extensive pattern and most of the arable lands were converted into factories and mines. Economic growth plays an important role in the changes of cultivated land area. The relationship between the GDP and the area of cultivation land area could be described as negatively logarithmic.

Population increase

The conflicts between increasing population and limited land area always constrain the sustainable development of the Yangtze Delta. Although the annual rate of regional population increase of 14.7% from 1949 to 1982 and 7.5% since the 1980s was lower than the national average during the same period, the population almost doubled within the past 50 years from 3453.3×10^4 in 1949 to 6346.6×10^4 in 1998. In 1994 average dwelling space of each urban dweller reached 71.4 m^2 and that of each rural dweller 152.7 m^2. Using this standard the new dwellings of the Yangtze Delta within the past 50 years amounted to 34.9×10^4 hm^2 which mainly came from the converting of croplands. In Suzhou, for example, rural and urban dwellings increased by 2495.3 hm^2 from 1994 to 1998. 79.6% of the newly added dwellings were built on croplands, comprising 1/3 of the total decrease in croplands.

Conclusion

With a high reclamation rate, low cultivation land area *per capita* and high input, the Yangtze Delta has a high comprehensive output value and a fast decreasing rate of arable land area.

The changes of arable land area in the Yangtze Delta within the past 50 years could be divided into four stages including three troughs. Most of the decreases were due to conversio of arable lands into factories and mines, dwellings and transport corridors. Any new croplands generally comes from the enclosing of wetlands and tidal areas.

Driving forces behind the changes include government policy, economic growth and population increase. Economic growth and population increase played a sustaining role in the decrease while government policy was usually connected with the sudden changes.

Except those specially noted the data comes from the almanac of China, the almanacs of Zhejiang, the almanacs of Jiangsu, the almanacs of Shanghai and the almanacs of corresponding cities and counties.

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5.5 Recent socio-economic changes related to environmental quality of the Pearl River Delta

*A. W.M. Wong and M.H. Wong**

Introduction

Dramatic restructuring of the Pearl River Delta (PRD) region (in the southern part of Guangdong Province) over the past two decades has led to significant industrialization and rapid change in land use. With the introduction of the open door policy and economic reforms in 1978, Guangdong Province was selected by the central government for economic development (Vogel 1989). The province became the fastest growing region with regard to its annual industrial output, tertiary output and export trade (Vogel 1989; Yeung and Chu 1994). The gross domestic product (GDP) of PRD increases at an average annual rate of 17.5%, valued at US$47 billion in 1995, some 72% of Guangdong Province's total GDP (Guangdong Province Statistical Bureau 1996). Moreover, many new cities have developed in previous agricultural counties. Tremendous changes in land-use patterns have taken place within a very short period of time (Yeh and Li 1999). These developments, however, were not well-planned or co-ordinated. Few environmental impacts were considered for such development. Thus, serious pollution problems in the region have been observed. The water quality of the Pearl River Delta has deteriorated with sources from untreated domestic sewage, industrial wastewater and rural non-point pollution. The present paper is an attempt to study the environmental quality of Pearl River with emphasis on water quality and its impact under rapid socio-economic changes.

Pearl River Delta Region

Pearl River System

The Pearl River (Zhujiang) is the largest river system in South China, and the fourth largest in the country, with three major tributaries, namely West River, North River and East River, merge together into the Pearl River Delta. The river is 2,218 km long with a catchment area of 450,000 km^2. The mean annual discharge is 330×10^9 m^3, and the sediment load is 70×10^9 kg yr^{-1} (Kot and Hu 1995). There are eight outlets (Yamen, Hutiaomen, Jitimen, Modaomen, Hengmen, Hongqimen, Jiaomen and Humen) through which the river water enters the estuaries and the South China Sea. The Pearl River is the region's main water resource and is considered as one of the most important nutrient suppliers to the north-west Pacific Ocean (Duan *et al.* 2000).

The Delta region

The delta (22°12' – 22°45'N, 113°33'– 114°09'E) covers an area of 4,000 km^2, 26% of the total land area of Guangdong Province. It is broadly triangular in shape, extending down both sides of the Pearl River estuary with the provincial capital of Guangzhou at its northern apex, Shenzhen Special Economic Zone (SEZ) at its south-east corner, and Zhuhai SEZ at its south-west corner. The Pearl River Delta lies in the subtropical zone with long summers and short winters, and an annual temperature of 21-22°C. The total rainfall is 1,600-2,000 mm $year^{-1}$, with 80% of the river's annual discharge in the wet season (April to September). Winds are southerly in summer and northerly in winter. Typhoons coincide with the high water season, and hence flooding is common, especially near the estuary. The province is frost-free, cumulative heat reaching the ground being 4,180-5,430 MJ m^{-2} $year^{-1}$ (Chau 1994). The PRD is a traditional farmland with many favorable physical characteristics, such as flat and fertile land, rich biological diversity, abundant fresh water and easy access to the sea for agricultural and aquacultural development. It is renowned for crop and fish production. There are eight major cities in the region, namely Guangzhou, Shenzhen, Zhuhai, Foshan, Zhongshan, Dongguan, Huizhou and Jiangmen. The population is about 21.2 million (1995), including 6.7 million in the Hong Kong Special Administration Region (SAR) and 0.5 million in the Macau SAR. Since the implementation of the open door policy, the PRD region has been integrated into the economic and cultural core of South China.

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*author for correspondence

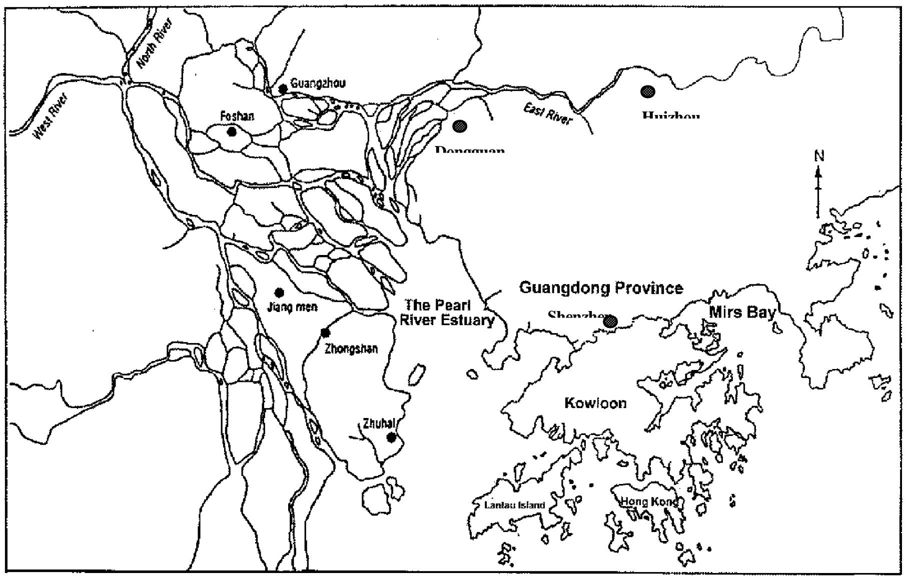

Figure 1. The Pearl River estuary and the eight major cities in delta region.

Development of the Pearl River Delta

Industrialization and economic growth

Between 1952 and 1978, the national income of Guangdong posted a low annual 5.3% growth compared to the national average of 6% in the same period. Since then there has been a tremendous change in the economic basis: with a substantial decline in agriculture, a slight increase in manufacturing and a substantial increase in services (Table 1). The provincial income grew at an annual average of 14.2 % due to the development of the market economy as well as the establishment of export-led industrialization (Maruya 1998). Export values amounted to US$53.7 billion in 1996. Although industrial production was originally confined to a few SEZs and industrial estates, the dispersal of industry from urban centres to satellite towns and rural areas has proceeded at a rapid rate within the Pearl River Delta (Neller and Lam 1994). Some medium-to-small investors from Hong Kong were moved to the region in order to escape from labour shortages and high land prices. About 20% of Hong Kong's smaller industrial enterprises have established contact with the delta region. There are various kinds of light, medium and heavy industries, with textiles, printing and dyeing, electroplating, tanneries, and beverage, food and paper manufacturing prevalent in the area (Wang and Peng 1993).

Table 1. Change of economic basis in China (New Zealand Trade Development Board 1998).

	1980	1993
Agriculture	26%	9%
Manufacturing	45%	51%
Services	29%	40%

Population

Although the natural rate of population increase is not high, immigration into the region contributes significantly to the overall population growth. The population increased from 9.62 million in 1982 to 21.2 million in 1996, including 6.7 and 0.5 million from Hong Kong and Macau (Guangdong Province Statistical Bureau 1996).

Agriculture

Extensive tracts of land have been converted from agricultural to urban and industrial uses. Land restructuring affected arable land which decreased by 20% during the 1980s (Duan *et al.* 2000). The remaining farmlands are either non-fertile or small. To maintain grain production *per capita* and high productivity in the region, enormous quantity of chemical fertilizers and pesticides (Tables 2 and 3) have been used to enhance the area yield per unit, especially the newly reclaimed agricultural land which has a low soil fertility. Between 1986 and 1989 there was a 40% increase in the consumption of chemical fertilizers. Up to 26×10^6 t of fertilizers were used in China in 1990 (Duan *et al.* 2000). In the recent years, about 194.7×10^4 t of chemical fertilizers (94.7×10^4 t N, 27.8×10^4 t P, 33×10^4 t K, and 39.2×10^4 t compound fertilizers) have been used in Guangdong Province (China Statistics Bureau 1998). Unfortunately, application of enormous amounts of fertilizer has not accomplished a great increase in production rate (Table 4), and excess nutrients are leached out to the river systems. Furthermore, use of organic wastes such as manure compost has declined, leading to accumulation of organic matters. Since mitigation measures are rarely used, agricultural surface runoff contribute to nutrient and organic pollution loadings within the delta and adjacent estuary (Neller and Lam 1994).

Table 2. Consumption of fertilizers in China (FAO 1999).

Year	Consumption (million t)
1961	728,000
1993	25,317,300
1999	36,134,180

Table 3. Import of pesticides to China (FAO 1999).

Year	Import Value (US$1000)
1961	27,000
1993	269,658
1999	296,429

Table 4. Trends in the use of chemical fertilizers.

Year	Application rate ($kg\ ha^{-1}\ yr^{-1}$)	Use of chemical fertilizer	Crop production
1950	0.05		
1960	0.4		
1970	2.3	Increase 489 times	Increase 32 times
1980	8.5		
1985	12.2		
1990	18.1		
1995	20.0		

Water Pollution

Socio-economic drivers such as population growth, industrialization and urbanization have created environmental pressures e.g., excess nutrient loads, organic contaminants and oil and have resulted in impacts on the coastal systems through eutrophication, algal blooms and contamination of water resources (Table 5). In addition to the various rapid developments, inadequate environmental management and planning and limited funds for infrastructure investment have all contributed to steady deterioration of river water quality (Tao and Hills 1999). It is believed that polluting industries have taken advantage of the decentralization policy and the failure to implement environmental controls within these newly developing regions, to substantially increase industrial effluent discharge into the Pearl River directly, without treatment. Furthermore, population increase has also produced more domestic sewage. These activities exceed the capacity of the river system.

It has been estimated that up to $2x10^9$ tonnes of industrial effluent and $560x10^6$ t of domestic wastes are generated annually within the region (Chen 1994). The river inflows in summer and winter are $1450x10^6$ m^3 d^{-1} and $360x10^6$ m^3 d^{-1} respectively (Wong and Cheung 2000). The wastewater discharged from the eight major cities of the region (Table 6) comprises almost 70% of the province's total discharges (Guangdong Province Environmental Protection Bureau 1996). There was a rapid increase in domestic discharge, but a slight decline in industrial discharge between 1991 and 1995 from the eight major cities (Table 7). Major pollution indices are nitrate nitrogen, manganese (IV) oxides and total mercury (Table 8; China Statistics Bureau 1998). In general, the estuary is affected by various physical, chemical and biological processes, and is characterized by a complex nutrient distribution (Wang and Tan 1989).

Table 5. Drivers, pressures and impact of Pearl River fluxes.

Drivers	Pressures	Impact on the coastal system
Rapid urbanization and Population growth	Domestic sewage (excess nutrients loads) Wastewater	Eutrophication HABs Oxygen depletion Contamination Loss of water resources
Economic growth	Wastewater Excess nutrients loads	Eutrophication
Industrialization	Effluents Organic contaminants (PAH, PCB, oil) Heavy metals	Eutrophication Contamination Bioaccumulation of POPs in aquatic resources and sediments Loss of water resources
Agriculture and irrigation	Excess nutrients (fertilizers), Organic contaminants (pesticides), Increased suspended solid transport (loose soil in reclaimed land), Water extraction (poor water holding capacity)	Eutrophication Contamination Decrease of coastal resources, excess suspended solids
Shipping industry/ Transportation	Oil	Oxygen depletion

Table 6. Wastewater discharges from the eight major cities of the Pearl River Delta region: 1991-95 (%) (Guangdong Province Environmental Protection Bureau 1996).

City	1991	1992	1993	1994	1995
Guangzhou	51.9	52.3	49.8	46.4	46.6
Shenzhen	8.2	9.2	10.6	11.8	12.0
Zhuhai	3.6	3.5	3.1	4.5	4.4
Dongguan	4.7	4.8	4.9	4.9	4.3
Huizhou	1.8	3.2	4.8	6.1	5.8
Foshan	12.9	12.6	11.7	11.5	12.1
Zhongshan	5.7	4.5	5.7	6.2	6.3
Jiangmen	11.1	10.0	9.3	8.7	8.6
Total	100	100	100	100	100
PRDR as % of Guangdong Province's total discharges	69.3	70.6	69.8	65.4	64.7

Table 7. Composition of wastewater discharges from the eight major cities of Pearl River Delta region: 1991-95 (10^4 t) (Guangdong Province Environmental Protection Bureau 1996).

Source	1991	1992	1993	1994	1995
Industry	83,755	82,803	82,982	79,797	76,183
Domestic	90,169	106,958	123,612	140,771	149,385
Total	173,924	189,761	206,594	220,568	225,568

Table 8. Water quality of Pearl River Water System, 1995-1999 (China Environment Yearbook 1996-1999).

Item	Unit	1995	1996	1997	1998
pH		6.88-8.39	7.2-8.4	7.27-8.35	7.1-8.4
Total suspended solid	mg/L	6.7-122.4	1.5-124.2	4.38-276.45	3.4-702.8
Total hardness	mg/L	2.60-61.18	0.40-44.71	1.26-42.24	0.62-50.87
Dissolved oxygen	mg/L	0.8-8.5	1.3-8.4	1.5-8.53	1.1-9.3
Manganese oxides	mg/L	1.4-6.3	1.4-7.7	0.79-7.29	0.7-6.8
BOD*	mg/L	1.0-4.4	0.5-5.8	0.44-4.5	1.0-4.0
Ammoniacal nitrogen	mg/L	0.008-3.287	0.021-4.487	0.0124-0.70	0.002-1.597
Nitrite nitrogen	mg/L	0.002-0.157	0.006-0.210	0.002-0.170	0.002-0.239
Nitrate nitrogen	mg/L	0.12-1.11	0.20-1.35	0.2-1.38	0.14-6.85
Volatile phenol	mg/L	0.001-0.005	0.001-0.006	0.001-0.005	0.001-0.005
Total cyanide	mg/L	0.001-0.002	0.002-0.003	0.0017-0.0038	0.001-0.003
Total As	mg/L	0.004-0.014	0.004-0.009	0.0039-0.0096	0.004-0.072
Total Hg	mg/L	0.00-0.0007	0.00003-0.00008	0-0.0001	0.00002-0.0002
Cr(VI)	mg/L	0.002-0.013	0.002-0.013	0.002-0.0106	0.002-0.017
Total Pb	mg/L	0.002-0.033	0.001-0.028	0.001-0.0439	0.001-0.039
Total Cd	mg/L	0.001-0.0046	0.0-0.00517	0.0001-0.0042	0.00010-0.00478
Petroleum category	mg/L	0.02-0.40	0.02-0.40	0.02-0.2225	0.02-2.50

*Biological oxygen demand

Nutrients and suspended solids

The Pearl River contains a large amount of suspended solids, which averaged 19.2 mg L^{-1} in the estuary (Wang and Peng 1992). 79.2% of the suspended matter is deposited in the estuary and only 20.8% dispersed into the South China Sea. Inadequate disposal of huge amounts of industrial and domestic wastewater is likely to give rise to the increasing in nutrients transport (Duan *et al.* 2000). The nutrient budget of the Pearl River estuary depends on organic inputs from surface runoff and from the river's upper channels (Wang and Tan 1989). After capture by suspended matter and salt or freshwater mixtures, a major fraction of the nutrients is deposited in the sediments or taken up by aquatic organisms (Wang and Peng 1993).

Nitrogen is transported in dissolved inorganic forms including nitrate, ammonium and nitrite. Nitrate accounts for more than 93% of the total dissolved inorganic nitrogen (DIN) with 0.3-1.1 mg L^{-1}, compared with ammonium and nitrite of 0.08 and 0.06 mg L^{-1} respectively. Concentration of nitrate is low in summer and autumn but high in winter and spring. On the other hand, the distribution of concentrations of nitrite and ammonia are opposite to that of nitrate. Hence the thermodynamic equilibrium of DIN has not been reached in either surface or bottom water (Wang and Peng 1993). The levels of DIN in summer and winter are 15 and 24 mmol m^{-3} accordingly, with a residence time of 40 days (Cheung *et al.* 2000).

The estimated annual input of P is 0.74×10^4 t with a residence time of 44 days (Wang and Peng 1993). Dissolved phosphate is generally high in autumn and winter, but low in spring and summer. Variation of dissolved P in the surface water provides a buffer (below 1 μmol L^{-1}) to salinity, and the concentration of P is less than that in the bottom water. The average concentration of P is particularly high during flood periods (June and August). This suggests that although some P might have been consumed by phytoplankton, discharges from the upper river are the prime source of total P in the estuary. The levels of DIP in summer and winter are 0.9 and 2.2 mmol m^{-3} accordingly (Cheung *et al.* 2000).

A study of C, N and P fluxes in the Pearl River Estuary (Wong and Cheung 2000) indicated that the high nutrient levels at the mouth of the estuary were due to the high net residual flow and exchange flow. The combination of residual flow and exchange flow between the estuary and ocean resulted in a higher nutrient export in winter than in summer. Water quality is comparatively stable, but seasonal variations are obvious. In the waterway network, the pollution by N is greater than that by P. The highest contents of N and P are 300 μM and 7 μM respectively in certain parts of the coastal ocean.

Pesticides
The river water enters from the south-east of the estuary, turns west at the top of estuary and finally drives out to the sea along the western coast. Therefore, the top and western portions of the estuary have suffered from more severe organic pollution by wave action (Wang and Peng 1993). Various indices show that organic pollutants have seriously affected the Pearl River. Chloro-pesticides carried by the Pearl River reached 863 t annually (the highest among China's rivers) and this ended up on the coast of South China. Concentrations ranged from 0.111 - 2.260 μg L^{-1} (average 1.00 μg L^{-1}) in Guangdong Province, with the highest concentrations found in the eastern part of the province, especially in spring, and the next highest in the Pearl River mouth in autumn. Concentrations of DDT and HCH in marine sediment were also high in the eastern part of Guangdong Province (Zheng 1997). Table 9 shows that the sewage discharged from Guangzhou (the provincial capital) contains the highest concentrations of HCHs (0.04-0.38 μg L^{-1}), DDE (0.27 μg L^{-1}) and DDT (0.23 μg L^{-1}) compared to those from Zhaoqing and Shenzhen, leading to the higher concentrations of these compounds detected in the Pearl River.

Table 9. Concentrations of organochlorines in water systems in the Pearl River Delta (□g L^{-1}) (Yang *et al.* 1997; Drinking Water Standard: Lu 1995).

Compounds	Sewage in Guangzhou	Sewage in Zhaoqing	Sewage in Shenzhen	Shenzhen River	Pearl River (Guangzhou)	Drinking Water Standard
α-HCH	0.38	0.01	0.03	0.01	0.24	n.a.
β-HCH	0.04	0.01	0.01	n.a.	n.a.	n.a.
γ-HCH	0.30	0.02	0.08	0.21	0.15	n.a.
DDE	0.27	0.02	0.01	0.1	0.21	n.a.
DDT	0.23	0.07	0.01	0.09	0.28	1

Persistent Organic Pollutants
Results of a preliminary study analyzing two persistent organic pollutants, polycyclic aromatic hydrocarbons (PAHs) and polychlorinanted biphenyls (PCBs) in river water and sediments of the Pearl River region (Wong, in manuscript) are summarized in Table 10. Total concentrations of AHS in river water and river sediment of 1.6 μg L^{-1} and 477-1137 μg kg^{-1} were obtained, which exceeded the Dutch Intervention Values (Netherlands Ministry of Housing 1994) (of 0.31 μg L^{-1} and 1000 μg kg^{-1} respectively. On the other hand, the river sediment was not contaminated by PCBs as the data (3.4-8.6 μg kg^{-1}) were all below the Dutch Intervention Values of 20 μg kg^{-1}.

Table 10. River contamination level of PAHs and PCBs in Pearl River Delta region (Wong *et al.* in manuscript).

		Guangzhou	Shenzhen	Hong Kong	Target Value
River water (μg L^{-1})	Total PAHs	1.6 (0.5-2.6)	1.6 (0.6-3.6)	1.6 (0.7-4.1)	0.31 [(a)]
River sediment (μg/kg)	Total PAHs	1137 (504-1623)	477 (178-822)	702 (170-2145)	1000[(b)]
	Total PCBs	3.4 (1.9-5.1)	3.4 (0.9-6.1)	8.6 (0.9-19.8)	20[(b)]

a. Target value for water, which is specified to indicate desirable uncontaminated chemical contents of water (Dutch Intervention Values, Netherlands Ministry of Housing 1994)

b. Target value for soil/sediment, which is specified to indicate desirable uncontaminated chemical contents of soil/sediment (Dutch Intervention Values, Netherlands Ministry of Housing 1994)

Oil

The concentration of oil has always been high in the Pearl River Estuary and the South China Sea. The mean concentration of oil in the estuary is 70 μg L^{-1} (40 to 90 μg L^{-1}) (China Seashore Investigation 1989). The Pearl River carries about 55,000 tonnes of oil pollutants to the South China Sea every year (Zheng and Tang 1997), with a higher loading in summer, but a lower loading in spring. The total loading rates ranged from 50-829 mg kg^{-1} d^{-1} in sediments of South China Sea and 531 mg kg^{-1} d^{-1} in the eastern part of Guangdong Province. Oil compounds in seawater mainly come from land, due to vehicle spills on highways, roads and streets, and are carried by rainwater into rivers, estuaries and coastal waters. Some pollutants may come from ships directly (Hoffman *et al.* 1983). In general, the Pearl River contributed about 30% (52224 t yr^{-1}) of total oil pollutants into China's coastal seas (Table 11) (China Seashore Investigation 1989), whereas oil discharged from Guangdong Province has contributed almost 39% of the total oil pollutants discharged among all coastal provinces (Table 12).

Table 11. Percentage of oil pollutant amount carried by rivers in China (Editor Group of China Seashore Investigation 1989).

Rivers and seas	Amount (t/a)	Percentage
Liaohe River etc. of Liaoning Province	3579	2.08
Luanhe River etc. of Hebei Province	115	0.07
Huanghe River etc. of Shandong Province	1615	0.94
Guanhe River etc. of Jiangsu Province	1986	1.15
Total entering Bohai and Huanghai Seas	7295	4.23
Changjiang River etc. of Shanghai	101635	59.01
Qiantang River of Zhejiang Province	7149	4.15
Minjiang River etc. of Fujian Province	3519	2.04
Total entering East China Sea	112303	65.20
The Pearl River etc. of Guangdong Province	52224	30.31
Qinjiang River etc. of Guangxi Province	435	0.25
Total entering South China Sea	172257	30.56

Table 12. Distribution of oil discharge from coastal provinces (China Seashore Investigation 1989).

Provinces and municipalities	Amount (t yr^{-1})	Percentage
Liaoning	8150	17.05
Hebei	1991	4.16
Tianjin	2555	5.35
Shandong	3852	8.06
Jiangsu	663	1.39
Total	17213	36.00
Shanghai	6488	13.57
Zhejiang	2875	6.01
Fujian	2403	5.03
Total	11766	24.61
Guangdong	18560	38.82
Guangxi	271	0.57
TOTAL	18832	39.39

Impact

The pattern of economic development evident in the Pearl River Delta since the late 1970s highlights the conflict between economic growth and environmental protection. Input of pollutants has led to eutrophication, algal blooms, oxygen depletion, contamination of water and loss of resources.

Eutrophication

The high nutrient concentrations may lead to deoxygenation of watercourses, offensive smells and eutrophication of the estuary and algal bloomings (evidenced by increasing red tides). It is extremely severe in lower reaches of the river. For the past twenty years, eutrophication has occurred frequently in the Pearl River estuarine zone (Ho and Hodgkiss 1991). Eutrophication is mainly due to the replacement of natural wetlands (which can cover and sequester nutrients) with man-made grow-out ponds that are highly enriched with fertilizers and served as sources of dissolved and particulate nutrients. The release of soluble inorganic nutrients from intensive fish and shrimp farming has aggravated the eutrophication problems (Qi *et al.* 1993). However, nutrients are probably not the limiting factor in the nutrient enriched system. Water residence time and/or salinity of the estuary might be limiting factors causing eutrophication (Cheung *et al.* 2000).

Red tides

Red tides frequently occur in Dapendwan, Dayawan, Shenzhenwan and river mouth of the Pearl River. These red tides are related to the embayment pattern and the occurrence frequency is high whereas the duration is relatively short. The western waters of Hong Kong have been worst affected, with the most severe case in 1998, due to a bloom of dinoflagellate *Gymnodinium mikimotoi*, resulting in massive fish kill valued at US$80 million. There were over 481 algal blooms reported in Hong Kong waters with fewer than 6% of these derived from the Pearl River estuary from 1980 to 1997 (Dickman *et al.* 1998). Five more harmful dinoflagellate species have been recorded in the South China Sea, namely *Prorocentrum minimum, P. micans, Alexandrium tamarense, A. catenella* and *Scrippsiella trochoidea* (Qi *et al.* 1994). These harmful algal blooms (HABs) have a variety of impacts on the marine environment, living marine resources, marine fisheries, mariculture and human health, due to the toxins produced by the algae or the high density of the blooming organisms.

Organic contaminants

Persistent organic pollutants (POPs) have contaminated both waters and sediments of the Pearl River Delta. They are hydrophobic and can bioaccumulate up the food chain, causing adverse effects on the environment and human health. The concentrations of in whale blubber from the South China Sea were 33 of DDTs and 2 mg kg^{-1} of PCBs (Parsons *et al.* 1999), while dolphin blubber from the Pearl River Delta contained 48 and 35 mg kg^{-1} respectively (Minh *et al.* 1999). A study on POPs in human breast milk from Hong Kong and Guangzhou indicated that the levels of □-HCH (0.95 mg g^{-1} of fat) and *p,p'*-DDT (2.68 mg g^{-1} of fat) were 2-10 times higher, whereas PCBs (0.035 mg g^{-1} of fat) were 10 times lower than levels in Europe (Denmark, Sweden, Great Britain and Germany) and Canada.

Attempts at environmental protection

Since the end of 1995 the Environmental Protection Bureau of Guangdong Province and environmental protection authorities in all urban cities and most counties have joined forces to tackle the problems (Lo and Cheung 1998). However, regulatory measures such as "environmental impact assessment" and "pollutants discharge fees" failed to control pollution or to prevent further environmental deterioration, although some areas (Zhuhai, Zhongshan, Foshan and Dongguan) have succeeded in limiting industrial sources. Due to poor implementation of environmental regulations, the Pearl River is now one of the most heavily polluted rivers in China (Neller and Lam 1998). In general, Guangzhou alone dumps 2.7x10^6 m^3 of sewage into the river without any treatment each day. In 1998, Guangzhou treated an average of only 300,000 m^3 of wastewater daily, a sewage treatment rate of roughly 11%. The entire river valley suffers an economic loss of US$35 million every year because of water pollution. It is acknowledged that more attention needs to be paid to the water resources of the Pearl River (China Environmental Reporter 1997). It has been estimated that the annual economic loss due to environmental degradation amounts to US$11 billion in the region. However, only a diminutive US$116.5 million (0.7% of GDP) is set aside for environmental improvement (Chan 1998).

Conclusions and recommendations

The Guangdong Government has been actively promoting economic development in the province since 1979 and now growth is prominent. However, because of poor implementation of environmental management in industrial and domestic sectors, the environment quality in Guangdong Province is deteriorating, especially in the Pearl River Delta. There is cross-boundary pollution in which Hong Kong environment is affected. The Pearl River receives hundreds of millions of tonnes of wastewater from the delta region every year and the water is seriously polluted. East River water quality (where the majority of drinking water in Hong Kong comes from) is now considered as unfit for drinking water. While wastewater has been rapidly increasing, the production capacity for water treatment has lagged behind. Obviously, this is a serious problem in environmental protection and sustainable development. To restore the water quality of Pearl River, it is necessary to enforce the pollution regulations and rules within the region including disposal cost and license and construction of more waste treatment plants to reduce the concentration of pollutants in treated sewage/effluent. Government authorities and private sectors should educate their staff on the importance of environmental protection. Environmental education is important to promote environmental awareness of the general public. In addition, there should be environmental planning for all industrial and urban development.

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5.6 The Pearl River estuary under global changes and its experimental observing system

Chaoyu Wu

<u>*Introduction*</u>

The Pearl River is the third largest river system in China. Its delta is located in Guangdong Province, South China (Figure 1). The Pearl River delta is densely populated and is an important industrial and agricultural area of China.

All the estuaries are geologically young, having been formed when sea level reached the present level approximately 6,000 years ago. Estuaries represent a geologically ephemeral transition zone, in which many features of geomorphology, water circulation, biogeochemistry and ecology are varied and diverse, leading to description and classification of different categories of estuarine system with unique combinations of characteristics (Caspers 1967; Pritchard 1967). Throughout the Quaternary Period (2 million years BP) and even in the last 15,000 years, eustatic sea-level changes have repeatedly shifted estuarine environment back and forth across continental shelves and coastal plains. These movements altered the character of individual estuaries by varying their geometry, river gradient, discharge and wave climate, which in turn have influenced salinity, circulation and sedimentation.

Long-term morphological and hydrographic behavior in estuarine coast in response to human interference and changing environmental conditions is an increasing important issue. We are becoming aware of the need for sustainable development and are facing threats such as accelerated sea level rise and climate changes in coastal and estuarine environment.

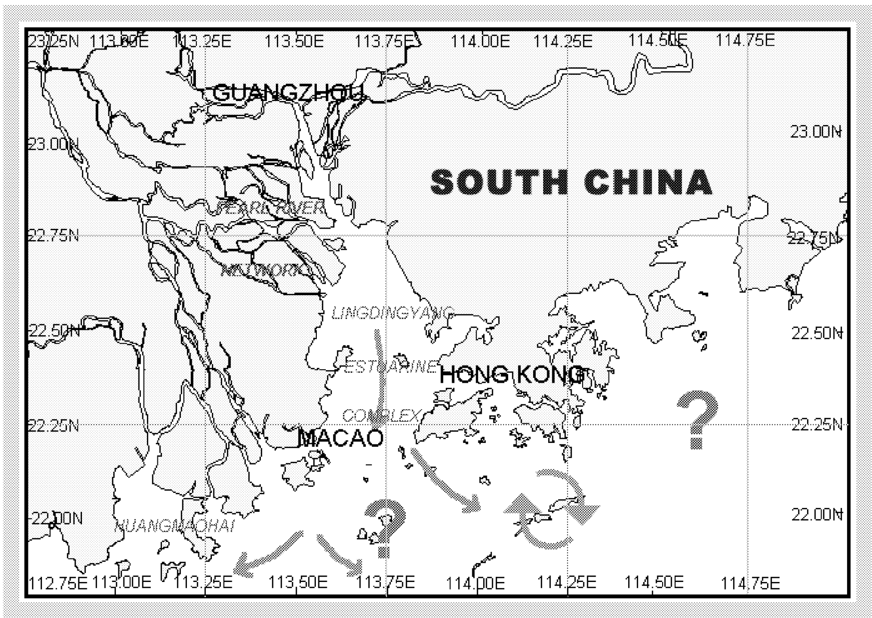

Figure 1. Schema of the Pearl River estuarine system.

Geological Setting

Is it a delta or not?

When a geographer or a geologist drives in the Pearl River delta, he will come across low terrain, hills and even mountains over 600 m high, surrounded by the low-lying plain and might not recognize that he is in a delta plain. This is what Heim (1929) thought. Is this a delta or not? Some said yes (Hubbard 1929); some said no (Chen 1934). The argument was finally settled when several sets of typical wave-cut caves with well-preserved wave-cut platforms and foreheads was found and identified (Wu 1937) in Qixing Hill (Seven Star Hill) in a suburb of Guangzhou (Canton) City, which indicates that the sea once reached at least to Guanzhou, which is some kilometers from the sea now. The variety of landforms makes the Pearl River delta unique. The hundreds, if not thousands, of hills scattered in the present delta plain were islands at some stage during the last 6,000 years. There are still more than 400 rocky islands along the Pearl River delta coast (Zhao 1992). They acted as nucleus for deposition of sediment carried by the rivers. Today no one argues the existence of the Pearl River Delta, but compared to the other coastal plain estuaries this evolution process has left many imprints on the deltaic estuaries and made them unique in many aspects.

Differential sedimentation along the two sides of the Lingdingyang Estuary

The coastal morphology and modern sedimentation processes on the two sides of Lingdingyang estuary display a sharp contrast. The coastline of Hong Kong, on the eastern side of the estuary, is a partially submerged, dissected upland rising to over 900 m in height. With numerous bays, headlands, projecting peninsulas and offshore islands, the coastline is highly crenulated and dominated by a ria form often associated with a steep underwater slope.

On the other side of the estuary including Macao, Zhuhai and Zhongshan, due to abundant sediment supply and deposition, the muddy coast is the dominant morphology. The coastline is smooth and with a very gentle underwater slope. The striking contrast is due to the differential sedimentation on the two sides of the Lingdingyang Estuary over the last five thousand years.

Evolution of the western Lingdingyang Estuary

The evolution of the coastline along the western side of the estuary has been associated with the development of the Pearl River Delta. Approximately 15,000 BP, at the end of the last regression, the sea level was 70-110 m below the present level on the south China coast. The coastline of the delta was some 200 km to the south.

When transgression peaked in 5000 BP, the sea level was not much different from the modern sea level. The coastline of the Pearl River delta migrated from north to south in different periods in the last five thousand years. Thousands of square kilometers of productive land gradually emerged from the shallow sea. At the same time, with the infilling of bays and tidal inlets, most of the potential deepwater harbors disappeared with the progress of the delta front.

Evolution of the eastern Lingdingyang estuary – the Hong Kong coast

The Hong Kong coast did not experienced substantial sedimentation. Each year approximately 80 million tons of suspended sediment is brought into coastal sea by the Pearl River through its eight outlets. Because of the geographical setting and Coriolis force most of the sediments are transported and deposited along the western side of the estuary including Macao, Zhuhai and Zhongshan. Very little suspended sediment from the river reaches Hong Kong coast crossing the Lingdingyang estuary. The most significant changes have been the result of the reclamation along the waterfront of Victoria Harbor in the last 150 years.

Dynamics of the Pearl River estuarine system

The Pearl River estuarine system can be divided, according to its dynamics, hydrography and morphology, into to two parts. The upper part is the stream network system. After entering the delta area, the West River, North River and East River, the three main tributaries of the Pearl River, bifurcate continuously and form a very complicated stream network system. The lower part includes several estuarine complexes and estuarine bays. Through eight major outlets, the fresh or brackish water from the network drains through these interconnected estuarine complexes to the South China Sea. The annual mean discharge of the Pearl River is 10,524 $m^3 s^{-1}$.

Rivers and sediment

Most of the Guangdong coast is in the South Asian subtropical monsoon climate zone. The total annual water volume discharging into the South China Sea is 3641×10^8 m^3. Within which 3260×10^8 m^3 is from the Pearl River, 241×10^8 m^3 from the Han River. The sediment concentration in the major rivers is about 0.10-

0.50 g l^{-1}. The total annual sediment carried by the rivers to the sea is over 1.0×10^8 tonnes, of which 71.0×10^6 tonnes come from the Pearl River and 7.3×10^6 tonnes from the Han River.

Approximately 20% of the total sediment entering the delta is deposited in the network channels and 80% is carried to the estuaries. The annual suspended sediment carried to Pearl River estuaries is about 71 million tonnes, of which about 80% is deposited in the estuaries and estuarine complexes and only 20% enters the coastal sea. Table 1 lists the annual mean of runoff and suspended sediment transported to the eight outlets of the Pearl River.

Table 1. Annual mean of runoff and sediment transported to Pearl River estuaries. (from Report on the Pearl River Delta Development Plan, Pearl River Water Conservation Committee(PRWCC) 1992). Units: runoff - 10^8 m^3; sediment - 10^6 tonnes.

	Hu Men	Jiao Men	Hong-Qili	Heng Men	Modao Men	JiTi Men	Hutiao Men	Ya Men	Total
Runoff	603	565	209	365	923	197	202	196	3260
%	18.5	17.3	6.4	11.2	28.3	6.1	6.2	6.0	100
Sediment	6.58	12.89	5.17	9.25	23.41	4.96	5.09	0.36	70.98
%	9.3	18.1	7.3	13.0	33.0	7.0	7.2	5.1	100

Special control morphology

Of the eight outlets of the Pearl River, seven have the suffix 'men', such as Humen (meaning tiger gate'), Modaomen (gate of sharpening a sword), Hutiaomen (gate of tiger jumping), Yamen (cliff gate). 'Men' means 'gate' in Chinese. A 'men' is located in the mouth of an estuary where rocky hills guard both sides of the outlet as a gate. These gates control the width of the estuaries at that point. The morphological outline and many aspects of the morphology-dynamics equilibrium are greatly affected by the location and physical size of these 'men'.

Tide

There are three major types of tides along Guangdong coast: (1) irregular semidiurnal tide, (2) irregular diurnal tide and (3) regular diurnal tide.

Tidal level: The maximum tidal level is caused by typhoons. The maximum tidal level in Nandu station is 5.94 m (Pearl River Datum). It is 3.0-3.4 m in the eastern Guangdong coast, 2.29-2.63 m in the Pearl River delta. The minimum tidal level of -3.45 m occurred to the west the Delta.

Tidal range: The mean tidal range in the eastern Guangdong coast is 1.5 m. It is 1.0-1.5 m in the Pearl River delta coast and 1.0-3.5 m in the western Guangdong coast. The maximum tidal range in the eastern Guangdong coast is 4.0 m. It is 2.5-3.5 m in the Pearl River delta coast and over 6.6 m in the western Guangdong coast (Table 2).

Table 2. Tidal range in the outlets of Pearl River estuaries.

Outlets stations	Hu Men Shanban-zhou	Jiao Men Nansha	Hongqili Wanqingsha	Heng Men Heng Men	Modao Men Denglong	Jiti Men Huangjin	Hutiao Men Xibaotai	Ya Men Huangchong
MFTR	1.60	1.36	1.21	1.10	0.86	1.01	1.20	1.24
METR	1.60	1.36	1.21	1.09	0.86	1.01	1.20	1.24
XFTR	2.90	2.72	2.79	2.27	1.90	2.44	2.51	2.73
XETR	3.36	2.57	2.57	2.48	2.29	2.71	2.52	2.95

MFTR = mean flood tidal range, METR = mean ebb tidal range (from Zhao 1992)
XFTR = maximum flood tidal range, XETR = maximum ebb tidal range

Subtidal fluctuations and their effects

A study on the sub-tidal sea level dynamic system from an extensive investigation on the "sea-river-atmosphere" system in the Pearl River Delta revealed large amplitude fluctuations within the sub-tidal range 0.01-0.5 cpd. (2-100 days). These fluctuations, according to power spectrum and coherence spectrum analysis, represent direct or indirect response of the estuary to variations in river inflow, wind stress and atmospheric pressure.

Frequency response analysis indicates that the maximum response of the estuary occurs at the frequencies 0.025-0.07 cpd (15-40 days). System simulations reveal, quantitatively, the relative importance and variations of the control variables on sea level in the estuarine complex. The volume transport caused by the low frequency components are one order of magnitude higher than that caused by the high frequency component even in fair weather. The low frequency components are important for the understanding of estuarine circulation, salt and sediment transport and the formation of turbidity maximum.

Small-scale dynamic structures and their effects on estuarine transport

In large scale estuaries such as Huangmaohai and Lingdingyang estuarine complexes, the dominant circulation alternates in different portions of the estuary because of the transition of the driving forces along the estuary. Based on field observations and theoretical considerations, the characteristics of SSDS's in the estuarine environment can be summarized as follows(Wu and Wu 1994):

(1) They are relatively stable with spatially and temporally variations and exist along the estuary alternately.
(2) With Rossby number ranges from 1 to 10 and Ekman number from 10^3 to 10^4 (with exceptions), they show the nature of small-scale structure and complexity, meaning that nonlinear effects and Coriolis force cannot be neglected.
(3) Because of the limited water depth in estuaries, the horizontal scale of the structure, ranging from several tens of meters to several tens of kilometers, is much greater than their vertical scale which, however, should not be ignored. They are rather sensitive to boundary conditions. A bottom Ekman layer may develop in the lower reach of estuaries.
(4) Residual circulation often forms within these structures. Very little is known about the energy and mass transition between structures. Discontinuous surfaces or fronts may be formed between systems.
(5) Finally, these dynamic structures are induced or driven by different forcing including density, momentum and buoyancy, boundary effects, Coriolis force and variation of vorticity.

These dynamic structures have profound effects on the function of the estuary. For example, because of the vertical non-tidal circulation, the volume transport capacity in the upper water column in the estuary can be an order of magnitude greater than the total river discharge with salt-water flow in from the lower water column.

Response to recent catchment and global changes

Secular trend of freshwater discharge: increasing

In estuarine areas, while fresh water discharges into the coastal sea, salt water also intrudes landward through advection and diffusion. Factors affecting salt water intrusion include estuarine geometry, dynamic equilibrium, river hydrography, tides and sea level changes and climate (precipitation and evaporation) etc. Geological response to sea level rise will depend on these factors.

The time-scale of interest for sea level rise varies from months to decades. Linear regressions were applied to historical records to determine the secular trend of fresh water discharge, chlorinity and tidal range in the major stations at the Pearl River outlets. Discharges at Sanshui, Makou and Bolo represent fresh water input to the Pearl River delta from the West, North and East rivers. Records of monthly and annual mean freshwater discharge at the three stations from 1959 to 1984 were collected and analyzed. Results indicate that freshwater discharge from all three tributaries increased during the study period. The average increasing rate is 34 $m^3 s^{-1} yr^{-1}$ at Makou, 7.0 $m^3 s^{-1}$ at Sanshui and 10 $m^3 s^{-1}$ at Bolo. The average increasing rate of freshwater entering the delta area is 51 $m^3 s^{-1} yr^{-1}$.

Secular trend of chlorinity: decreasing

During the study period, chlorinity at all stations of the eight outlets has been slowly decreasing. The order of decrease for monthly records is 10^{-3}-10^{-4} ppt m^{-1}, yearly mean records is about 10^{-2}ppt yr^{-1}. The main causes are freshwater input increase and estuary extension.

Chlorinity response to sea level rise: a statistics approach

For a given station, the monthly mean chlorinity for flood slack tide is mainly affected by monthly mean freshwater discharge, tidal range and mean sea level. A regression analysis conducted on the monthly mean tidal range and monthly mean sea level indicates a high correlation between the two variables. Therefore, independent variables can be reduced to mean sea level *SL* and discharge *DS* with respect to dependent variable chlorinity *CL*. A one-dimensional regression between *CL* and *SL* was conducted using *DS* as category parameters on several major stations. For all calculation, *SL* refers to monthly mean sea level at Chiwan station in Lingdingyang. *DS* refers to total monthly mean discharge from Makou, Sanshui and Bolo stations. At Guancheng station, water stage is used as a parameter instead of discharge. Under a given discharge category or interval, a simple regression is established for each station:

$$Cl = k\ SL + B + \varepsilon$$

Monthly mean chlorinity response to sea level rise under different discharge categories. k and B are calculated.

Sea level rise in South China

Falling or Rising? - Some previous study indicates that sea level in the eastern Asian area has been falling instead of rising since the 1950's (Barnett 1984, Douglas, 1993).

Effect of high frequency sea level variations - High frequency components (*HFC*) in tidal records have critical effects, which can be expressed in analytical form, for the determination of secular trends from time series less than 40-50 years.

Rate of sea level rise - A calculation scheme was designed to remove *HFC* and estimate the secular trend. Sea level rise along the South China coast calculated with this scheme is 1.7-1.9 mm yr^{-1}, similar to the global sea level rise (Table 3).

Table 3. Secular trend of water stage in South China coast and Pearl River delta.

Station	Time span	Mean sea level Monthly mean record	Change rate Annual mean record
Hong Kong	1950-1992	0.34	0.34
	1959-1988	1.91	1.92
	1959-1992	1.91	1.91
Zhapo	1959-1988	1.68	1.68
Wanqingshaxi	1959-1988	2.31	2.31
Huangpu	1959-1988	0.40	0.40
Fubaochang	1959-1988	0.61	0.64
Hengmen	1959-1988	3.00	2.90
Denglongshan	1959-1988	2.03	2.03
Zhuyin	1959-1988	1.90	1.96
Chiwan	1965-1988	0.51	0.72

Impacts

When cumulative MSLR exceeds 0.5-1.0 m, the area of farmland in the Pearl River delta threatened by salt water will increase from 0.112 million *ac.* to 0.164-0.277 million *ac.*. At the same time, the major waterworks in Guanzhou city will be forced to relocate. The total additional investment of RMB1.70 billion yuan will be needed due to MSLR to maintain the standard of the coastal protection system.

Environmental issues

Of the total pollutants draining into the South China Sea, more than 85% is from river inflow. which is about 671.3×10^3 t yr^{-1}. The Pearl River accounts for more than 80% of this.

Experimental observing system

A series of estuarine predictive skill experiments has been carried out by Center for Coastal Ocean of Science and Technology Research (CCOST) at Zhongshan University in the Pearl River estuary since 1999. It is the first attempt to establish the Pearl River Estuary Integrated Observing System (PEIOS). The present stage is to evaluate a set of data-assimilative, estuarine and coastal ocean forecasting models coupled to a multi-platform adaptive-sampling network in a dynamic, rapid-change and data- and process-rich environment. The observing network of PEIOS includes meteorological, oceanographic and environmental data, shore- and space-based remote sensing and monitoring platforms and a shipboard platform with cruises for physical and biogeochemical observations. Numerical models are special modules in PEIOS for simulation and prediction of estuarine dynamics and pollution including current velocity, suspended sediment concentration, water quality parameters, e.g., COD, DO, inorganic and organic phosphorus. See http://ccar.ust.hk/cis for more information about PEIOS.

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5.7 Decadal and millennial time-scale changes of water and sediment discharge of the Huanghe (Yellow River) caused by human activities

Zuosheng Yang, Yoshiki Saito, Baozhu Liu, Jun Zhang and Houjie Wang

Introduction

The Huanghe (Yellow River) originates on the Tibetan Plateau, and flows into the Bohai Sea, where the modern Huanghe delta has been forming since 1855. The total length of the Huanghe is about 5,464 km, with a drainage basin area of about 7.52×10^7 km^2 and a population of about 97.8 million. The Huanghe is second longest of the Chinese rivers, and it was second in the world in terms of sediment load (e.g., Milliman and Syvitski 1992). However, in recent years the Huanghe has become a seasonal river: no-flow events have been occurring in the lower reaches of the Huanghe since 1972 (Deng *et al.* 1997; Zhang and Yang 1998). Furthermore, water and sediment discharges of the Huanghe into the Bohai Sea have been decreasing steadily since the 1970s due to increased human activities, resulting in erosion in the coastal zone of the Huanghe delta, salt water intrusion, and other environmental problems (Qin *et al.* 1993; Xi 1996; Zhao 1996; Yang *et al.* 1998a, 1998b, 2000). Sediment discharge of the Huanghe has also changed on a millennial time scale. Before 1000 years ago, the sediment discharge of the Huanghe was 1×10^8 t yr^{-1}, one-tenth the present level. An abrupt increase occurred about 1000 years ago as a consequence of human activities on the Loess Plateau, especially cultivation and deforestation. Moreover, the estimated sediment load of the Huanghe at Sanmenxia station prior to 1000 years ago was 2.7 to 4.0×10^8 t yr^{-1}, or about 20% (15%-25%) of the present level. This paper reviews sediment discharge of the Huanghe on time scales of both decades and millennia.

Decadal changes

Water discharge

Water discharge from the Huanghe to the sea since the 1950s has been sharply reduced (Qin *et al.* 1993; Xi 1996; Yang *et al.* 1998a, 1998b, 2000; see Table 1). Multi-year (1950-1999) average water discharge at the Lijin Hydrographic Gauge, about 105 km upstream from the river mouth, was 37.6×10^9 m^3 y^{-1}. Sharp reductions occurred in the 1970s and 1990s. Water discharge in the 1990s was only about a third of that in the 1950s or 1960s. This water discharge reduction has reduced nutrient input to the coastal sea which served as food for shrimps, thus causing a reduction in mariculture production due to food limitation.

Table 1. Multi-year average water and sediment loads in the Huanghe River, 1950-1999.

Decade	Water discharge (m^3)	Sediment load (tonnes)
1950-1959	49.1×10^9	1.30×10^9
1960-1969	50.1×10^9	1.17×10^9
1970-1979	39.6×10^9	0.878×10^9
1980-1989	33.7×10^9	0.657×10^9
1990-1999	15.5×10^9	0.287×10^9
Mean (1950-1999	**37.6×10^9**	**0.86×10^9**

Sediment load

Sediment discharge from the Huanghe to the sea since the 1950s also has been sharply reduced (Qin *et al.* 1993; Yang *et al.* 1998a, 1998b, 2000; Table 1). Multi-year (1950-1999) average sediment discharge at the Lijin Hydrographic Gauge was about 0.86×10^9 t yr^{-1}. Sharp reductions occurred in the 1970s and 1990s. Sediment load at the Lijin Hydrographic Gauge in the 1990s was only about 22% of that in the 1950s, or 24% of that in the 1960s. This sediment discharge reduction has caused intensive erosion in the coastal zone in the Huanghe delta due to lack of sediment supply. Large areas of new-born wetland have disappeared due to the erosion.

No-flow events in the lower part of the Huanghe

The Huanghe has become a seasonal river, and both the no-flow days and the length of no-flow channel extending upstream in the lower reaches of the Huanghe have been increasing steadily in recent years (Deng *et al.* 1997; Zhang and Yang 1998; Table 2). The first no-flow event at the Lijin Hydrographic Gauge occurred on 23 April 1972 (Zhang and Yang 1998). In 1972, the total no-flow days were 19 and the maximum length of no-flow river channel was about 330 km. The beginning date and ending date of no-flow events also has been changing to earlier and later, respectively. In the 1970s, the earliest no-flow date was April 23, 1973 and the latest ending date was July 11, 1974. In the 1980s, the earliest beginning date was April 4, 1989, and latest ending date was October 17, 1987. In contrast, in the 1990s, the earliest beginning date was February 7, 1997 and the latest ending date was December 23, 1997. These results show that the flow conditions of the Huanghe has been deteriorating since the 1970s, and the no-flow conditions of the lower reaches of the Huanghe also contributed to the reduction of sediment supply to the delta and loss of wetland areas.

Table 2. No-flow events in the Huanghe River.

Decade	Total number of no-flow days	Year with maximum number of no-flow days	Maximum no-flow channel length, year
1970-1979	86	21 (1979)	350 km (1974)
1980-1989	105	36 (1981)	800 km (1981)
1990-1999	1036	226 (1997)	600 km

Causes of recent changes

These sharp reductions of water discharge and sediment load, and the increases of the no-flow days and the length of no-flow channel of the Huanghe may most probably be caused by the increased human activities in the Huanghe drainage basin area.

Precipitation in the Huanghe drainage basin area has been increasing since the 1970s (Xi 1996). In other words, the water source for the Huanghe has been increasing, thus, the water discharge and sediment load should not have been decreasing if there were no human influences. For the upper reaches of the Huanghe, the total annual precipitation was about 800 mm in the 1950s, 540 mm in the 1960s, 890 mm in the 1970s, 1150 mm in the 1080s, and 1355 mm in the 1990s. For the middle reaches of the Huanghe, the total annual precipitation averaged about 1100 mm in the 1950s, 790 mm in the 1960s, 1195 mm in the 1970s, 1550 mm in the 1980s, while 1910 mm in the 1990s. In total, precipitation for the upper and middle reaches of the Huanghe in the 1990s was about 1.7 times that in the 1950s and 2.5 times that in the 1960s.

Table 3. Average precipitation and water consumption along the Huaghe River, 1950-1999.

Decade	Upper Huanghe		Middle Huanghe		Lower Huanghe
	Precipitation (mm yr^{-1})	Consumption (m^3 yr^{-1})	Precipitation (mm yr^{-1})	Consumption (m^3 yr^{-1})	Consumption (m^3 yr^{-1})
1950-1959	800 mm	7.3×10^9	1100	3×10^9	1.9×10^9
1960-1969	540 mm	9.5×10^9	790	4.9×10^9	3.3×10^9
1970-1979	890 mm	10.3×10^9	1195	6.3×10^9	8.4×10^9
1980-1989	1150 mm	12.1×10^9	1550	6.2×10^9	11.3×10^9
1990-1999	1355 mm	13.2×10^9	1910	6.0×10^9	10.8×10^9

On the other hand, water consumption also has been increasing since the 1970s (Deng *et al.* 1997). More than 200 large irrigation systems and eight large reservoirs and hydroelectric installations have been built along the Huanghe. For the whole Huanghe drainage basin, total water consumption was about 12×10^9 m^3 yr^{-1} in the 1950s, 18×10^9 m^3 yr^{-1} in the 1960s, 25×10^9 m^3 yr^{-1} in the 1970s, 29×10^9 m^3 yr^{-1} in the 1980s and

30×10^9 m^3 yr^{-1} in the 1990s. The present amount is equivalent to about 60% of the water discharge at the Lijin Hydrographic Gauge station in the 1950s and 1960s. The reductions in the early 1970s in water and sediment discharge were mainly caused by dam construction, e.g., the dam that created the Sanmenxia Reservoir. However the sharp flow reduction and dry-up of the Huanghe in the 1990s were results of water consumption in the whole drainage basin. The largest reservoir along the Huanghe, the Xiaolangdi Reservoir, designed to have a water storage capacity of 12.7×10^9 m^3 and a sediment storage capacity of 10×10^9 tonnes, is now being built in the middle reaches of the Huanghe (Yang *et al.* 2000). After the completion of the Xiaolangdi Reservoir, more water will be consumed and less sediment is expected for the lower reaches of the Huanghe.

Nowadays, more than 30×10^9 m^3 of the Huanghe water are consumed annually, taking up about 55% of the total Huanghe water resources (Yang *et al.* 2000). This water consumption is for industrial, agricultural and domestic uses. The water demands from these activities are still increasing due to active development in the drainage basin.

Millennial changes

Past sediment discharge of the Huanghe on millennial time scale is estimated from the volume of marine sediments around the Bohai and Yellow seas (Saito *et al.* in press).

A sudden increase in sediment discharge occurred ca. 1,000 years BP. The sediment discharge prior to 1000 years ago was estimated to be only one-tenth the present level, which is almost same value that Milliman *et al.* (1987) derived (Saito *et al.* in press). Sediment load of the Huanghe at Sanmenxia is estimated from the total Holocene sediment volume of the North China Plain (alluvial fan) and deltas (Saito *et al.* in press). The present sediment transport rate at the Sanmenxia and Lijin stations is $1.6x10^9$ t yr^{-1} and $1.1x10^9$ t yr^{-1}, respectively. The difference between the rates measured at these stations represents the rate of sediment accumulation in the North China Plain. If this rate has been constant for the last 1,000 years, the total sediment yield during that period was $5x10^{11}$ tonnes. The total mass of Holocene sediments in the North China Plain is ca. $2x10^{12}$ tonnes (assuming an area of $8x10^{10}$ m^2, a thickness of 20 m, and a dry bulk density of 1.2 g cm^{-3}). Therefore, $1.5x10^{12}$ tonnes ($2x10^{12}$ t - $5x10^{11}$ t) of sediment accumulated from 10,000-8,000 to 1,000 years BP, which means that the average annual sediment accumulation prior to 1000 years BP can be estimated to have been 1.7 to $2.1x10^8$ t yr^{-1} ($1.5x10^{12}$ t over 7,000 to 9,000 years). Since the marine sediment accumulation in the deltas (coastal areas) was $1x10^8$ t yr^{-1} from 6,000 to 1,000 years BP, total sediment accumulation in the North China Plain and deltas was 2.7 to 3.1 x 10^8 t yr^{-1}. This rate is only 17% to 19% of the present sediment discharge at Sanmenxia station and about half the rate estimated by Ren and Zhu (1994), which is $5x10^8$ t yr^{-1}. The above estimate supposes that a 20 m thickness of sediments was deposited during the last 8,000 to 10,000 years. However, if these sediments were deposited during only the last 6,000 years, the rate was $4x10^8$ t yr^{-1}, which is still lower than the rate estimated by Ren and Zhu (1994). Therefore, the sediment load of the natural-state Huanghe at Sanmenxia is estimated to have been between $2.7x10^8$ and $4x10^8$ t yr^{-1}, or about 20% (15% to 25%) of the present level. In this estimate, sediments dispersed into the Bohai and Yellow seas were not precisely calculated. At present, 70% to 90% of the sediments passing Lijin Station form the Huanghe Delta (Qin and Li 1983; Saito and Yang 1994). Based on sediment volume of deltaic sediments, the dispersal effect is negligible, because past sediment discharge was calculated from the ratio of the past to the present sediment discharge.

During the last 2,000 years, the Loess Plateau has been drastically changed. The population in the plateau increased from 700,000 during the Han Dynasty (206 BC-220 AD) to 60 to 70 million during the Tang Dynasty (618-907 AD) (Hu *et al.* 1998). The name of the Huanghe has also changed from "large river" *(Da He)* before 2,500 years ago, to "turbid river" (*Zhuo He)* in the Han Dynasty, to "Yellow River" (*Huang He*) in the Tang Dynasty (Hu *et al.* 1998). Grass-covered and forested lands in the Loess Plateau decreased from 53% of the total land area before 2,500 years ago to only 3% at present (Wang and Aubrey 1987). These drastic changes resulted in soil erosion, a high concentration of sediments in the river water, and frequent floods (Vörösmarty *et al.* 1998). Historical records show a very strong correlation between flood events and past sediment discharge of the Huanghe. Moreover, the delta of the Huanghe has changed from a smooth linear coastline to the present elongate or bird's-foot topography, which means that the main shaping force has changed from the waves to the river (Galloway 1975). This change is also concordant with an increase in sediment discharge of the Huanghe.

Conclusion

The Huanghe is one of the best examples of human impacts on sediment discharge. The river has experienced various human activities for the last 4,000 years as both changes of the increase of sediment yield due to cultivation and deforestation, and the decrease of sediment load by dam construction, irrigation and other water usage. These drastic changes teach us the tremendous influences of human activities on natural systems.

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5.8 Decadal and millennial time scale changes of water and sediment discharge of the Changjiang (Yangtze River) caused by human activities

Yoshiki Saito, Zhongyuan Chen, Jiufa Li, Huanting Shen and Kazuaki Hori

Introduction

The Changjiang (Yangtze) River is one of the largest rivers in the world in terms of suspended sediment load, water discharge, length and drainage area. The river has formed a broad tide-dominated delta at its mouth since 6-7,000 years (kyr) BP (Wang *et al.* 1981; Li and Li 1983), when sea level reached or approached its present level (Zhao *et al.* 1979; Chen and Stanley 1998). The Changjiang is in excess of 6,300 km long and has a drainage area of 1.94×10^6 km^2 with a population of about 400 million. It is the fourth largest river in the world in terms of suspended load (480×10^6 t yr^{-1}) and and fifth largest in terms of water discharge (921 km^3 yr^{-1}) (Milliman and Meade 1983). About 70% of the annual water discharge occurs during the flood season (May to October). Sediment discharge during the flood season constitutes 87.2% of the annual sediment load. Most of the suspended sediments are silts and clays. The huge drainage basin can be divided into the upper, middle and lower reaches, primarily on the basis of geological context and climate settings, and secondarily on the basis of the resulting fluvial geomorphology of the river.

The present mean tidal range is 2.7 m near the river mouth, and the maximum tidal range approaches 4.6 m (Shen *et al.* 1988). The tidal current reaches an average of 210 km upstream from the river mouth (Shen 1998). The tidal-current limit moves downstream from the average position about 30 km during the flood season and upstream about 80 km during the dry season (Shen 1998). The mean and maximum wave heights at the river mouth are 0.9 and 6.2 m, respectively. The waves are mainly wind-driven waves and secondarily swell. The wind-driven waves approach the coast mainly from the north in winter and from the south in summer.

Decadal changes

An internal report, "Annual Report on Changjiang Water and Sediment" (Changjiang Water Conservancy Committee 1875-1985) shows decadal changes of water and sediment discharges. The data set of three major hydrological stations at Yichang, Hankou and Datong, representing the upper, middle and lower Changjiang, respectively, were analyzed in detail by Chen *et al.* (2001).

The frequency of major discharge peaks along the Changjiang drainage basin increases downstream. There was almost no single major discharge peak in the upper Changjiang drainage basin in the last century ($>5.5 \times 10^4$ m^3 s^{-1}). In contrast, five major peaks of this size occurred in the middle Changjiang drainage basin within the same time period, and even more peaks (at least 9 times from 1950-1985) occurred in the lower Changjiang drainage basin.

A trend to decreasing sediment load for Yichang and Hakou was recognized for the period of 1950-1980. This trend is due to reduced discharge over the last 30 years. This reduction in discharge over that time period may be attributed to water diversion for intensifying agriculture along the upper and middle Changjiang stream. Rather than decrease, the sediment load at Datong of the lower Changjiang increased gradually, which is associated with the increase in sediment concentrations at all three stations, especially with Yichang. The overall increase in sediment concentration along the river may reflect the recent intensifying human impact, such as widespread deforestation in the upper Changjiang drainage basin (Higgitt and Lu 1996). Sediment loss due to human activity in the upper Changjiang could cause greater increase in sediment concentration downstream than the gentle rate observed at Hankou and Datong. This gentle increase in sediment concentration possibly results from numerous small- to medium-scale dams constructed in the upper Changjiang drainage basin, mostly during the 1950s to 1970s. This has reduced the volume of sediment discharging to downstream Changjiang (*cf.* Lu and Higgitt 1998).

Millennial changes

The Changjiang River, one of the largest rivers in the world, has formed a large delta at its mouth since about 6-7 kyr BP, when sea level reached or approached its present position. Most studies of the active extension of the subaerial delta plain from about 2 kyr BP (Wang *et al.* 1981; Chen *et al.* 1985; Chen 1996) were based only on paleogeographic maps and on land chenier studies. A recent study (Hori *et al.* 2001) shows changes of progradation rates of the Changjiang delta by analyzing samples from three boreholes (CM97, JS98, and HQ98) drilled in the present subaerial delta plain with high-resolution radiocarbon dates since 6 kyr BP.

The progradation rate increased abruptly about 2 kyr BP, going from 38 to 80 km kyr^{-1}. This rapid progradation can be correlated with the active extension of the subaerial delta plain estimated by Wang *et al.* (1981) and the rapid growth of the southern part of the subaerial delta, where cheniers have developed (Wang *et al.* 1981; Chen *et al.* 1985; Chen 1996, 1998). The increase in the progradation rate probably reflects the change in sediment discharge to the river-mouth area, because the longitudinal profile of the deltaic deposits show little variation in thickness. Considering the funnel shape of the Holocene delta plain and the depth of the prodelta, the annual sediment volume deposited in the delta-front and prodelta areas must have been increasing over the last 2 kyr.

There are several possible causes of the active progradation:
(1) an increase in sediment production, particularly suspended sediment, in the drainage area due to widespread human activities, such as intensive rice cultivation and deforestation (Chen *et al.* 1985; Jiang and Piperno 1999).
(2) a relative decrease in deposition in the middle reaches in relation to river-channel stability. Extensive flood plains and numerous natural lakes occur in the middle reaches of the river between Yichang and Hukou. Even now, the middle reaches are frequently subject to heavy flooding during the rainy season, and more than 20% of the suspended sediment load that passes through Yichang station is trapped in Dongting Lake (Chen *et al.* 2001). The cooling of the climate after the mid-Holocene together with the construction of dikes might have decreased the flooding in the middle reaches, resulting in the relative increase in sediment discharge to the river-mouth area.

If sediment production in the drainage basin has showed little increase during the last 6 kyr, we can estimate proportional sediment deposition in the middle and lower reaches before and after 2 kyr BP by applying the following two assumptions:
(1) The change in delta progradation rates reflects approximately the change in sediment load carried to the lower reaches and the delta area. Deltaic deposits showed little variation in thickness in the longitudinal profile. Therefore, sediment discharge in the lower reaches after 2 kyr BP must have been almost double the amount of discharge before 2 kyr BP. Because the delta is funnel shaped, this estimate is expected to be a minimum.
(2) Presently, one-third to two-fifths of the sediment discharge from the upper reaches is trapped in the middle reaches (Shi *et al.* 1985; Chen *et al.* 2001), and the remainder is deposited in the lower reaches and delta area. Because the effect of sediment discharge from the tributaries in the middle and lower reaches is not taken into account, this assumption is also a minimum estimate.

Based on these two assumptions, we estimated that the middle reaches trapped at least three-fifths to two-thirds of the sediment discharge before 2 kyr BP. Even though this estimate is a minimum, the depositional pattern in the middle reaches *versus* the lower reaches and delta area reversed at that time (Saito *et al.* 2001).

The shift of the Yellow River mouth from the Bohai Sea to the Yellow Sea did not directly contribute to this phenomenon. Because the Yellow River debouched into the Yellow Sea in Jiangsu Province from 1128 to 1855 AD, the change to rapid progradation of the Changjiang delta occurred about 1 kyr before the course change of the Yellow River. Sediment supply from the old Yellow River, however, must have increased progradation rates on the coastal plain of Jiangsu Province during the last 1 kyr.

Conclusion

Land use and human activities in the drainage area of the Changjiang have been rapidly changing on the decadal and millennial time scales and have had impacts on the coastal area.

On a decadal time scale (1950-1980), sediment load in the upper and middle reaches had been decreasing along with water discharge, probably due to water diversion for intensifying agriculture of the region. In contrast, an overall but very gentle increase in sediment concentration occurred along the entire Changjiang and caused increase in sediment load in the lower reaches. This phenomenon can be attributed to human activity, such as deforestation and damming in the upper drainage basin of the Changjiang (Chen *et al.* 2001).

On a millennial time-scale, recent borehole studies show that the progradation rate of the Changjiang River delta after 2 kyr BP was almost double the rate before 2 kyr BP. This change in the progradation rate correlates well with the active extension of the subaerial delta plain showed by chenier studies. Widespread human activities, such as farming, deforestation, and dike construction, probably resulted in an increase in sediment discharge to the river-mouth area. The reason for this rapid progradation is particularly considered to be a depocenter shift from the middle reaches of the river basin to the lower reaches and the delta (Hori *et al.* 2001).

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5.9 Effects of pollutants on the marine ecosystem of the Changjiang estuary

Masataka Watanabe, Hiroshi Koshikawa and Mingyuan Zhu

Introduction

The Changjiang River is the major source of freshwater, sediments and nutrients that flow into the East China Sea and the north-eastern Pacific Ocean, which is one of the most productive oceanic shelves in the world in terms of biodiversity and standing stocks. Human activity in the Changjiang catchment area, including industrialization, agriculture and water-resource development such as the construction of the Three Gorges Dam, may affect the aquatic, elemental and energy cycles of the catchment area. Ultimately, the supply of freshwater, sediments and nutrients to the East China Sea will be altered and, therefore, the structure and function of the East China Sea ecosystem may be affected.

A collaborative research project on 'Environmental loading from river inputs and their effects on the marine ecosystem in specified areas of the East China Sea' was established between the National Institute for Environmental Studies (NIES) and the State Oceanic Administration (SOA) of China. The objective of the project is to provide a scientific basis for management measures to protect the environment and resources of the East China Sea, through research in such areas as the evaluation of environmental capacity for pollution and the prediction of its effects on the ecosystem of the East China Sea.

A field survey and mesocosm experiments were conducted during 10-20 October 1997 and 14 May - 3 June 1998. The Chinese research vessel 'Haijian 49' (1000 gross tonnes) was used and the following research institutes participated in the cruises: NIES; Geological Survey of Japan; Seikai National Fisheries Research Institute; National Research Institute of Aquaculture; First Institute of Oceanography, SOA; Second Institute of Oceanography, SOA; East Sea Branch, SOA; and the Ocean University of Qingdao. The field survey area and the location of the mesocosm experiment are shown in Figure 1. The study area is controlled by two water masses, diluted water from the Changjiang River and offshore water of the East China Sea. NOAA AVHRR data during the project's two cruises in 1997 and 1998 indicated that highly turbid water from the Changjiang River was spread along the coast of China (Figure 2); the field survey area was located around the frontal zone of these two water masses.

Freshwater discharge from the Changjiang River, China, to the estuary amounts to about 9.24×10^{11} m^3 yr^{-1}. Nutrients carried by riverwater provide an essential resource for primary productivity in the marine ecosystems of the Changjiang Estuary and other estuarine systems (Bennekom *et al.* 1978; Edmond *et al.* 1981) Inorganic nitrogen is considerably richer in the Changjiang estuarine water (e.g., 20-50 μM of NO_3^-) than it is in other large rivers such as the Amazon (Harrison et al. 1992). However, concentrations of PO_4^{3-}

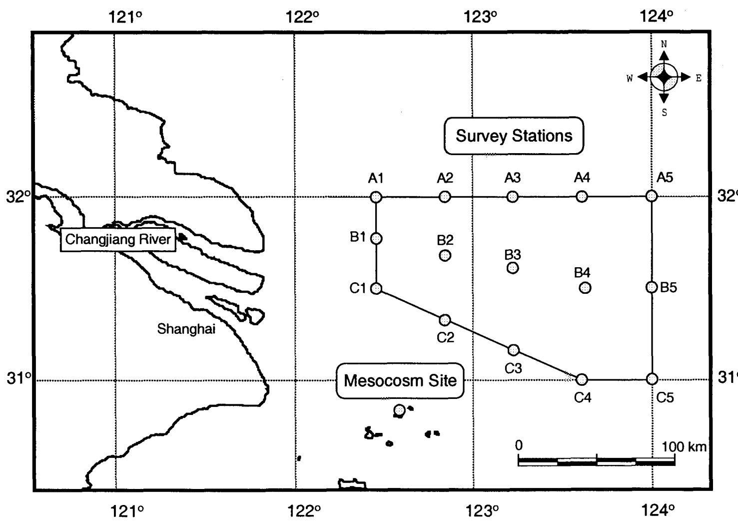

Figure 1. Locations of the mesocosm experiments and the sampling stations for the field survey.

range from 0.2 to 1 μM, which is comparable with those of other rivers, resulting in an environment with a high N/P ratio where phosphate is the limiting nutrient for phytoplankton growth (Edmond *et al.* 1985). One explanation for the high N/P ratio in the estuarine water is that a large quantity of excess nitrogen is discharged from the many large cities in the Changjiang river catchment, and from agricultural lands where much nitrogen but little phosphorus fertilizer is used. In addition, phosphates may be adsorbed by suspended particles that sink to bottom in the river mouth, carrying the phosphates with them (Edmond *et al.* 1985).

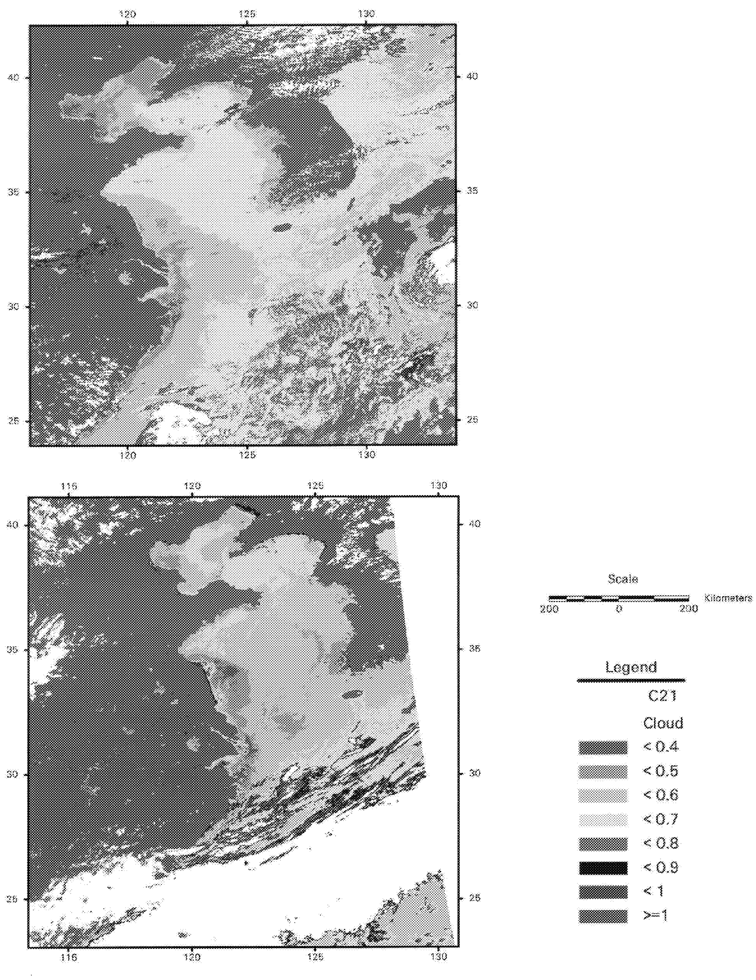

Figure 2. Distribution of turbidity during cruises in the east China Sea a) October 1997; b) May 1998 (data from NOAA AVHRR).

It is presumed that the recent rapid growth of the Chinese economy will cause excess nutrient loading through the river. The quality of these nutrients may also change with changes in agricultural practices, people's life-styles, etc. Furthermore, with development of the catchment area for flood control (e.g., construction of the Three Gorges Dam), it is presumed that there will be fewer suspended particles reaching the estuary (Chinese Academy of Science 1998). These factors may cause an increase in the total amount of nutrient loading and/or a change of nutrient quality (e.g., a decrease in the N/P ratio) and will affect the marine ecosystem involving the composition of plankton species, the structure of the food chain, and the elemental cycle in the Changjiang Estuary.

The goal of our research is to understand how the marine ecosystem and its biological carbon cycle will be affected by the nutrient load and the disturbance that will occur in the near future. In the present study, we assumed a situation in which the N/P ratio decreases with an increased supply of phosphate into the estuary through the river. We carried out phosphate enrichment experiments using marine mesocosms in the Changjiang Estuary area about 100 km from the river mouth in October 1997 (autumn) and May 1998 (spring). Mesocosms that capture natural marine environments enable us to investigate the responses of the ecosystem to nutrient disturbance (Grice and Reeve 1982).

Marine mesocosm and experimental site

A pair of bag-type floating mesocosms was deployed twice near Liuhuashan – Huanaoshan (30°50'N, 122°37'E) in the Changjiang estuarine area for 8 days from 10 October (day 0) to 17 October (day 7), 1997 (autumn) and for 9 days from 18 May (day 0) to 26 May (day 7), 1998 (spring). Each mesocosm (5 m deep, 3 m diameter, volume about 25 m^3) was made of ethylene-vinyl-acetate reinforced with a polyester grid; they were translucent (light transparency about 50%) with no chemical release from the surface. On the evening of day 0, in both autumn and spring, seawater was introduced into the pair of mesocosms through the bottom valve almost simultaneously to capture seawater from the same mass as far as possible. The paired mesocosms filled with seawater were moored to the stern of the anchored research vessel 'Haijian 49' of the State Oceanic Administration, China.

Nutrient concentrations (N, P) of the mesocosms were roughly determined on board the research vessel just after installation of the mesocosms (evening of day 0). Phosphate ($NaH_2PO_4 \cdot 2H_2O$) was then added to one of the paired mesocosms at night, lowering the N/P atomic ratio of the mesocosm seawater to about 10 (P-mesocosm). The mesocosm without added phosphate was a control system (C-mesocosm).

We deployed the autumn mesocosms in the area of sea north of Huanaoshan Island, a site which is more directly influenced by the Changjiang river water than is the southern area. However, a storm surge threatened to sink the C-mesocosm and it was salvaged onto the vessel on the evening of day 1 making it impossible to take samples from the C-mesocosm in the autumn experiment. Consequently, in the spring experiment, we deployed both mesocosms in the area of sea south of the island. Conditions in this area were relatively calm, though the ocean current was more likely to be affected by the insular geography (i.e. some small scattered islands) and seawater involving less Changjiang fresh water often flowed into this area. The P-mesocosm could be deployed through the whole spring experimental period (9 days) and the C-mesocosm was deployed for 7 days.

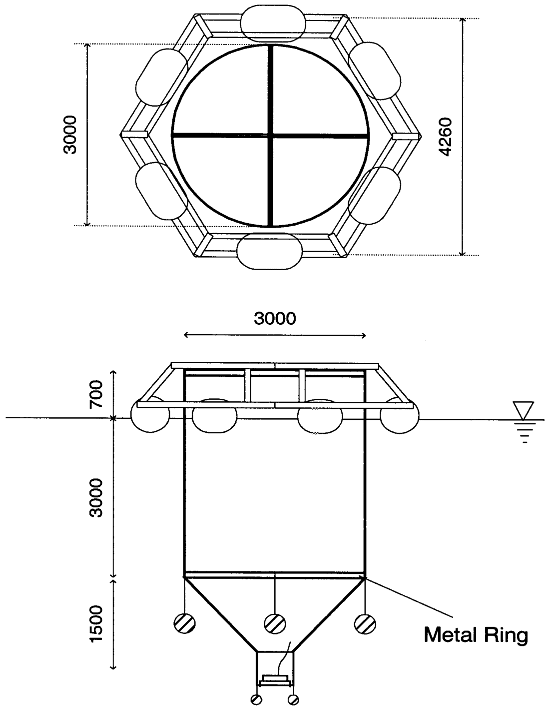

Figure 3. Schematic illustration of the mesocosm.

Results

Seawater temperature and salinity in the mesocosms

Daily average seawater temperatures within the mesocosms were 23.0°C in the autumn and 19.6°C in the spring (Figure 4). The daily changes in seawater temperatures inside and outside the mesocosms were almost synchronized.

Vertical profiles of seawater temperature and salinity (not shown) were almost the same each day, indicating that the water mass of each mesocosm was almost completely homogeneously mixed.

Nutrient conditions

Initial N/P atomic ratios of macronutrients in the P-mesocosms (day 0) were about 38 in the autumn ($[NH_4^+]$ = 0.5 μM, $[NO_3^-]$ = 24 μM, and $[PO_4^{3-}]$ = 0.65 μM) and about 94 in the spring ($[NH_4^+]$ = 1.2 μM, $[NO_3^-]$ = 16 μM and $[PO_4^{3-}]$ = 0.18 μM) (Figure 5). These N/P ratios were considerably higher than the Redfield Ratio, implying that the mesocosm ecosystems were P-limited. Initial concentrations of $[Si(OH)_4]$ were 40 μM (autumn) and 29 μM (spring).

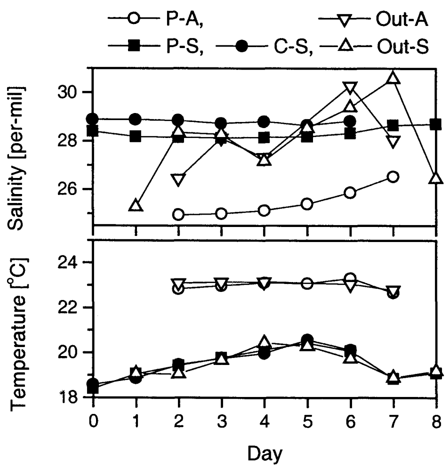

Figure 4. Temporal changes in salinity and seawater temperatures inside (average values at 1, 2 and 3 m depths) and outside mesocosms (average values at 1 - 5 m depths). P-A: P-mesocosm in autumn; Out-A: outside mesocosm in autumn; P-S: P-mesocosm in spring; C-S: C - mesocosm in spring; and Out-S: outside mesocosm in spring.

After adding PO_4^{3-} to the P-mesocosms on the night of day 0, the phosphate concentrations in the P-mesocosms increased to 3.1 μM (autumn) and 2.2 μM (spring) by the next morning (day 1). The phosphate concentrations then began to decrease rapidly, reaching 0.51 μM on day 5 (autumn) and 0.16 μM on day 6 (spring) - lower than their initial concentrations. The concentrations of NO_3^- also decreased concomitantly with the phosphate and became <0.1 μM on day 5 (autumn) and day 6 (spring). The phosphate additions decreased the day 1 N/P atomic ratios to about 7.2 in the autumn and 8.0 in the spring. The N/P ratios continued to decrease and reached minimums of 1.2 in autumn and 6.4 in spring. The concentrations of $Si(OH)_4$ in the autumn mesocosm decreased from 40.2 μM (day 0) to 0.7 μM (day 5) but, in the spring mesocosms, the decrease was only from 29.0 to 20.6 μM. The reduced consumption of silicate in the spring would be caused by the difference in dominant phytoplankton (i.e., diatoms were predominant in the autumn and dinoflagellates predominant in the spring, as described in more detail later).

In the C-mesocosm of the spring experiment, the concentrations of PO_4^{3-} and $Si(OH)_4$ showed little

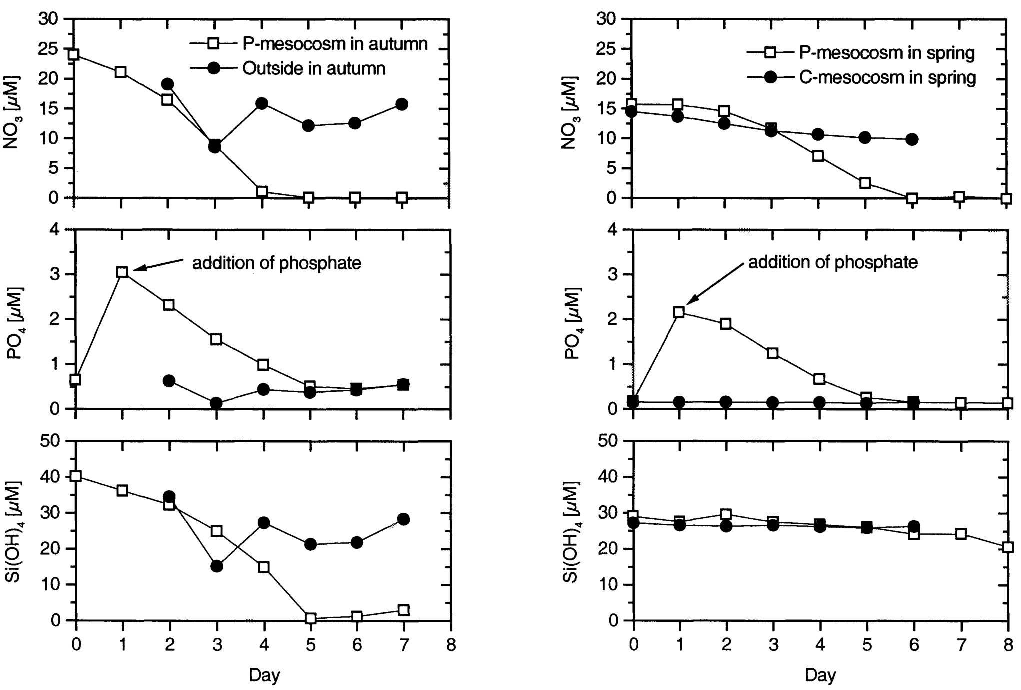

Figure 5. Temporal changes in concentrations of macronutrients in the autumn and spring experiments.

fluctuation with ranges of 0.14 - 0.16 μM and 27.2 - 25.9 μM, respectively. Only the NO_3^- showed a decreasing trend - from 14.5 μM (day 0) to 9.9 μM (day 6). However, the rate of NO_3^- decrease in the C-mesocosm was clearly slower than that in the P-mesocosm, suggesting that NO_3^- uptake by organisms in the C-mesocosm was limited by available phosphate.

Plankton abundance and activity of photosynthetic and bacterial producers

a) P-mesocosm in autumn, 1997

The initial concentration of POC (day 0) in the autumn P-mesocosm was 0.42 mgC l^{-1} (Figure 6). As the nutrients decreased, the POC continually increased and reached 1.78 mgC l^{-1} on day 6. Photosynthetic production was highest on day 1 (39.4 μgC l^{-1} h^{-1}) and continued with relatively large values until day 4. After day 6, however, the production was very low (4.0 – 4.8 μgC l^{-1} h^{-1}). POC also decreased from 1.78 to 1.00 mgC l^{-1} from day 6 to day 7). The tendency of the daily change in DOC concentration was similar to that of POC; it increased from 1.30 mgC l^{-1} (day 2) to 2.22 mgC l^{-1} (day 6) and afterward decreased somewhat.

The initial phytoplankton assemblage in the autumn P-mesocosm was comprised of more than 90% diatoms (the dominant species was *Skeletonema costatum*) (Figure 7). The cell density of diatoms increased gradually from 1.4×10^2 (day 1) to 1.0×10^4 cells ml^{-1} (day 5). Afterwards, it decreased rapidly and reached 0.5×10^2 cells ml^{-1} on day 7. Chl_*a* increased from 4.8 (day 1) to 18.7 μgChl_*a* l^{-1} (day 4) concomitantly with the abundance peak of dominant diatoms, and decreased rapidly from day 5 to 6 (Figure 6).

The major zooplankton (>100 μm) groups observed in the P-mesocosm were copepods (mainly *Paracalanus* sp. and *Oithona* sp.) and appendicularians (*Oikopleura* sp.) (Figure 7). Copepods were observed throughout the whole period. Their abundance showed a tendency of increase from day 1 (11 individuals l^{-1}) to day 7

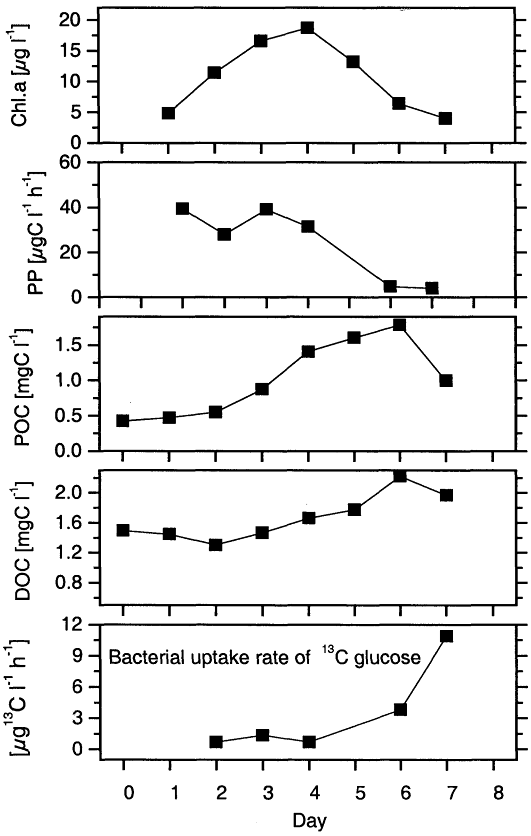

Figure 6. Daily changes in Chl_*a*, photosynthetic production (PP), POC, DOC and bacterial uptake rate of ^{13}C-glucose in the autumn P-mesocosm.

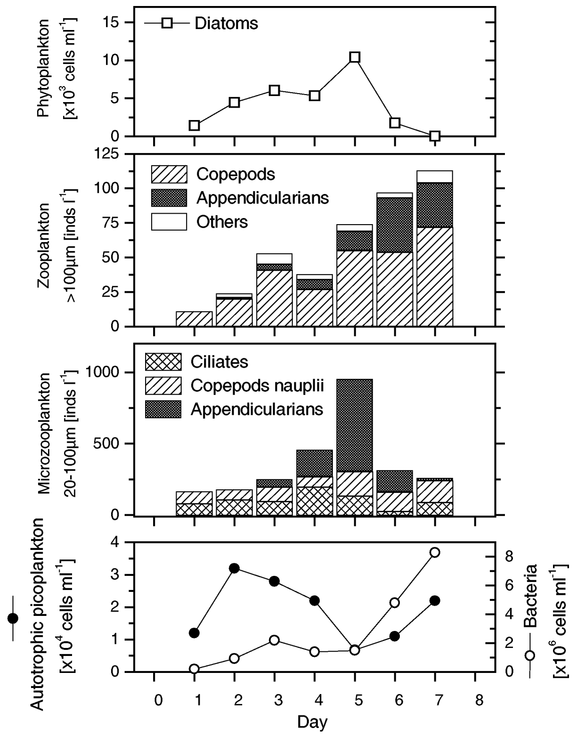

Figure 7. Daily changes in abundances of organisms in the autumn P-mesocosm.

(72 individuals l^{-1}). Appendicularians were first observed on day 3 and their abundance reached a maximum on day 6 (39 individuals l^{-1}).

Among the micro-sized zooplankton (20 – 100 μm), copepod nauplii, appendicularians, and ciliates were observed in the P-mesocosm. Among them, the appendicularians increased suddenly from day 3 (54 individuals l^{-1}) to day 5 (6.5×10^2 individuals l^{-1}), and became the dominant zooplankton in this size class (Figure 7).

Bacterioplankton density increased slightly and formed the first peak on day 3 (2.2×10^6 cells ml^{-1}), and subsequently decreased a little from day 3 to day 4. It then increased dramatically to its maximum on day 7 (8.3×10^6 cells ml^{-1}) (Figure 7). Bacterial activity, determined by ^{13}C-glucose uptake, increased from 0.68 (day 2) to 10.9 $\mu g^{13}C\ l^{-1}\ h^{-1}$ (day 7) (Figure 6) concomitant with the increase of bacterial abundance (Figure 7). Abundance of APP (autotrophic picoplankton) increased slightly from day 1 (1.2×10^4 cells ml^{-1}) to day 2 (3.2×10^4 cells ml^{-1}), but subsequently decreased rapidly from day 2 to day 5 (6.8×10^3 cells ml^{-1}). By day 6, APP had reverted to nearly its initial abundance (Figure 7).

b) P- and C-mesocosms in spring, 1998

Initial concentrations of POC (day 0) were 0.55 mgC l^{-1} and 0.22 mgC l^{-1} in the C- and P-mesocosms, respectively (Figure 8). Chl_*a* concentrations were 1.8 (C-mesocosm) and 0.8 μgChl_*a* l^{-1} (P-mesocosm). These results indicated that, right from the start of the experiment, there was more biomass in the control mesocosm than in the phosphate-enriched mesocosm. This was probably due to the patchiness of the seawater, despite the fact that the two mesocosms were enclosed almost simultaneously.

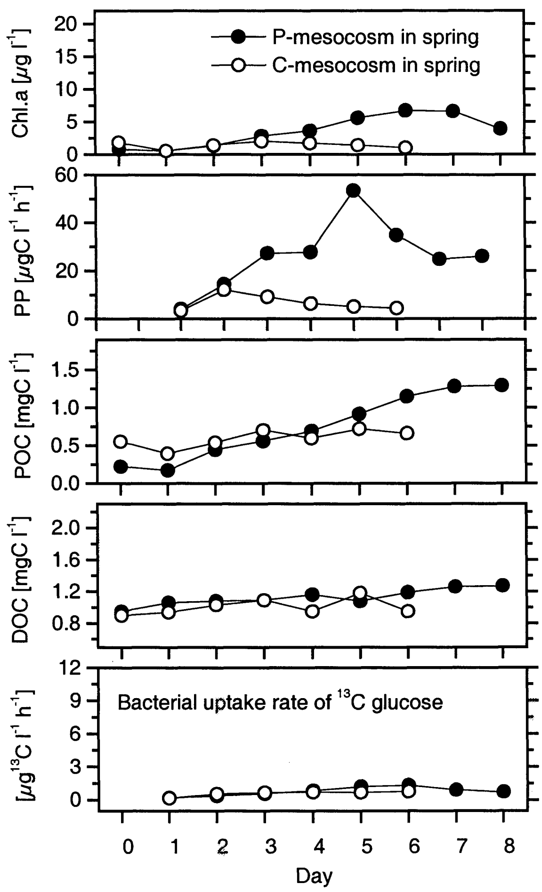

Figure 8. Daily changes in Chl_*a*, photosynthetic production (PP), POC, DOC and bacterial uptake rate of ^{13}C glucose in the spring P- and C-mesocosms.

In the P-mesocosm, POC concentration increased continually with a decrease in nutrients and peaked on day 8 (1.29 mgC l^{-1}). Photosynthetic production also increased gradually from 4.1 μgC l^{-1} h^{-1} (day 1) to 53.5 μgC l^{-1} h^{-1} (day 5) and then decreased to 26.1 μgC l^{-1} h^{-1} (day 8). The trend of daily change in the photosynthetic production in spring was different from that in the autumn P-mesocosm (i.e., in the autumn, the largest value was observed on day 1, and it decreased until the end). An almost continuous increase in DOC concentration was observed in the P-mesocosm but the range and the mean of all the concentrations were smaller (i.e., 0.95 - 1.27 mgC l^{-1}, mean = 1.13 mgC l^{-1}) than in the autumn mesocosm (average = 1.67 mgC l^{-1}).

In the C-mesocosm, no clear increase of POC concentration was found, but the POC fluctuated (0.39 - 0.72 mgC l^{-1}, average = 0.60 mgC l^{-1}) around the initial value (0.55 mgC l^{-1}). Daily changes in photosynthetic production remained within the range of 3.5 to 12.1 μgC l^{-1} h^{-1} and the mean (6.8 μgC l^{-1} h^{-1}) was approximately one quarter of that in the P-mesocosm. Chl_*a* concentration also showed no tendency to increase. DOC concentration showed a slight increase and smaller mean than that in the P-mesocosm.

Initially, phytoplankton in both mesocosms consisted almost entirely of dinoflagellates (the dominant species was *Prorocentrum dentatum*) (Figures 9 and 10). In the P-mesocosm, the abundance of dinoflagellates

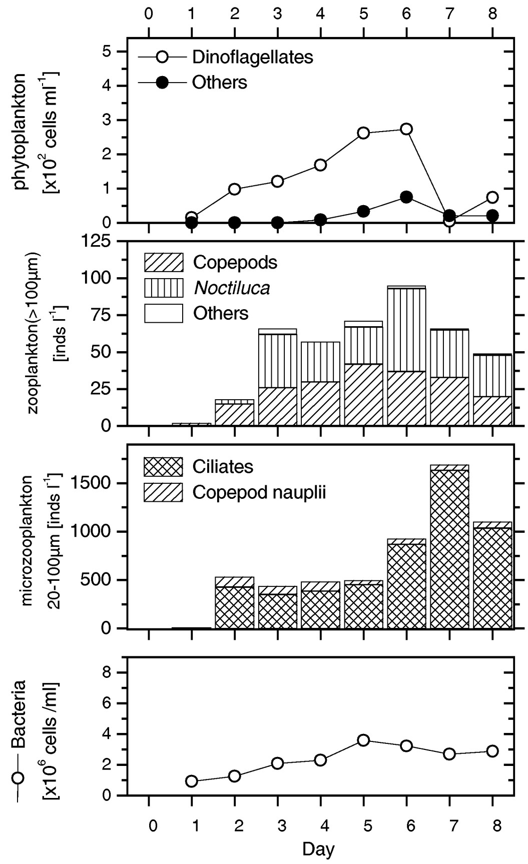

Figure 9. Daily changes in abundances of organisms in the spring P-mesocosm.

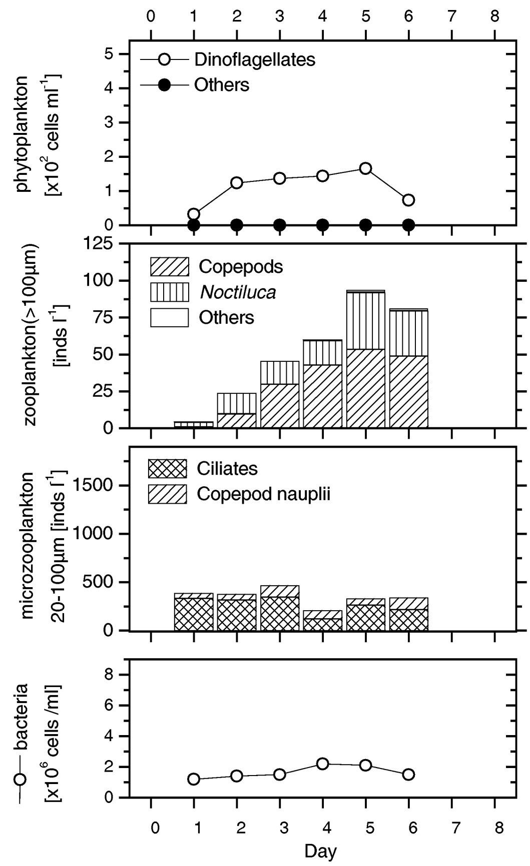

Figure 10. Daily changes in abundances of organisms in the spring C-mesocosm.

increased gradually from 2×10 cells ml^{-1} (day 1) to 2.7×10^{2}cells ml^{-1} (day 6) (Figure 9). In the C-mesocosm, on the other hand, though the minimum abundance was counted on day 1 (3×10 cells ml^{-1}), only a small daily change was observed with a range of 0.7 - 1.7×10^2 cells ml^{-1} after day 2 (Figure 10). In the P-mesocosm, diatoms (*Skeletonema costatum*) began to be observed on day 4 and they increased slightly to reach 0.8×10^2 cells ml^{-1} on day 6.

In both mesocosms, large-sized organisms (>100 µm) consisted of copepods (mainly *Paracalanus* sp., *Oithona* sp. and *Corycaeus* sp.) and *Noctiluca scintillans*, which is a heterotrophic dinoflagellate (Figures 9 and 10). The abundance of copepods in the P-mesocosm was 0.5 individuals l^{-1} on day 1 which subsequently increased to 31 individuals l^{-1} on day 7 (Figure 9). *N. scintillans* was first observed in large numbers on day 3 (36 individuals l^{-1}) and peaked on day 6 (56 individuals l^{-1}). Overall, the abundance of copepods was higher in the C-mesocosm than in the P-mesocosm and increased to 49 individuals l^{-1} on day 6 (Figure 10). The abundance of *N. scintillans* in the C-mesocosm was comparable with that in the P-mesocosm.

The micro-zooplankton (20 - 100 µm) samples comprised mainly copepod nauplii and ciliates (Figures 9 and 10). In the P-mesocosm, the initial abundance of ciliates (day 1) was very small but they increased rapidly from 4.3×10^2 individuals l^{-1} (day 2) to 1.6×10^3 individuals l^{-1} (day 7). In the C-mesocosm, on the other hand, their abundance changed within only a small range from 1.2 - 3.5×10^2 individuals l^{-1}.

The initial density of bacterioplankton (day 0) was 8.1×10^5 cells ml^{-1} in the P-mesocosm and 1.1×10^6 cells ml^{-1} in the C-mesocosm. In the P-mesocosm, cell density increased until day 5 (3.6×10^6 cells ml^{-1}) and afterward decreased somewhat (2.9×10^6 cells ml^{-1} on day 8) (Figure 9). In the C-mesocosm, a slight increase was observed, but the value of 2.2×10^6 cells ml^{-1} (day 4) was the maximum (Figure 10). The average of the bacterial activity was slightly higher in the P-mesocosm (0.77 $\mu g^{13}C\ l^{-1}\ h^{-1}$) than in the C-mesocosm (0.58 $\mu g^{13}C\ l^{-1}\ h^{-1}$) (Figure 8). However, activities in the spring P- and C-mesocosms did not show any of the conspicuous increases that were observed in the latter period of the autumn P-mesocosm experiment.

Proportion of ^{13}C-label transfer from producers to grazers

The net transformation of the ^{13}C label from dissolved to particulate carbon for each size fraction was calculated as the excess ^{13}C ($\mu g^{13}C\ l^{-1}\ 4\ h^{-1}$) against the natural abundance of the carbon isotope (Equation 1):

$$^{13}C_{ex} = (a_s - a_n) \times POC \qquad (1)$$

where a_s is the ^{13}C atom% of a given size fraction in the incubated sample and a_n is the ^{13}C atom% in the natural sample. POC ($\mu g\ l^{-1}$) is the particulate organic carbon in a given size fraction. The >100 μm fraction would comprise mostly the metazooplankton assemblage.

To determine the relative significance of carbon transfer to metazooplankton through bacteria and autotrophs, we calculated the proportion of ^{13}C-label transferred to the >100-μm fraction ($PLT_{>100\mu m}$, %) as the amount transferred to the >100-μm fraction ($^{13}C_{ex,>100\mu m}$) over the total transferred to all fractions ($^{13}C_{ex,all}$) (Equation 2):

$$PLT_{>100\mu m} = \left(\frac{^{13}C_{ex,>100\mu m}}{^{13}C_{ex,\ all}} \right) \times 100 \qquad (2)$$

The PLT represents the proportion of carbon fixed by bacterioplankton or autotrophs and conserved in the particles that may be transferred to metazooplankton by their feeding activities during the 4-hour incubation. A proportion of the fixed ^{13}C-label will, however, be respired by the producers themselves and by some intermediaries such as heterotrophic protists. The PLT is an incubation time-dependent value but can be an index of the degree of ease with which carbon passes through the trophic levels to metazooplankton (Koshikawa *et al.* 1996).

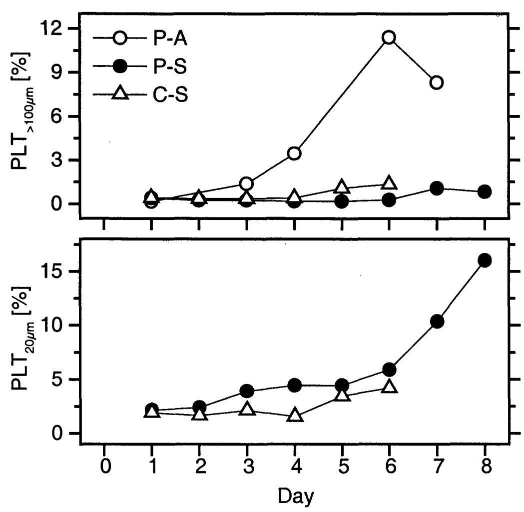

Figure 11. Daily changes in $PLT_{>100\mu m}$ and $PLT_{20\mu m}$ of the photosynthetic pathway.
P-A: autumn P-mesocosm; P-S: spring P-mesocosm; and C-S: spring C-mesocosm.

The proportion of ^{13}C-label transferred to the 20 to 100-μm fraction ($PLT_{20\mu m}$) was also calculated to consider the transfer of bacterial carbon and photosynthetic carbon to micro-sized grazers when the phytoplankton assemblages were comprised of small autotrophs (<20 μm).

Photosynthetic production was estimated by summation of the rates of carbon transformation from DIC to particles in each size fraction; the calculation was based on the ^{13}C method of Hama *et al.* (submitted). Bacterial activity was estimated by total fixation of ^{13}C-glucose into particulate matter.

With the ^{13}C tracer experiments, the proportion of the ^{13}C label that was transferred ($PLT_{>100\mu m}$) in the photosynthetic pathway in the autumn P-mesocosm where diatoms were predominant, was initially less than 0.2% (day 1) and subsequently increased to 11% on day 6 (Figure 11). In the spring P-mesocosm where dinoflagellates were dominant, however, $PLT_{>100\mu m}$ in the photosynthetic pathway remained lower throughout the experiment period (average = 0.5%) and the maximum was only 1.1%. The $PLT_{>100\mu m}$ in the spring C-mesocosm was of almost the same magnitude (average = 0.7%).

The $PLT_{20\mu m}$ of the photosynthetic pathway in the spring (Figure 8) gradually increased in both P- and C-mesocosms but tended to be higher in the P-mesocosm than in the C-mesocosm. The $PLT_{20\mu m}$ in the autumn is not shown here because, according to our microscopic analysis, a significant proportion of the dominant *Skeletonema* would be in the 20 – 100-µm fraction (GALD of a colony for *S. costatum* was about 25 – 50 µm).

The $PLT_{>100\ \mu m}$ values in the bacterial pathway were initially slightly larger in the spring P-mesocosm than in the autumn P-mesocosm, but after day 4 the PLTs in the autumn P-mesocosm rose suddenly (Figure 12). The $PLT_{20\mu m}$ of the bacterial pathway in the autumn showed a similar tendency of change as the $PLT_{>100\mu m}$ in that season. Consequently, the overall $PLT_{>100\mu m}$ and $PLT_{20\mu m}$ in the bacterial pathway were higher in the autumn than in the spring.

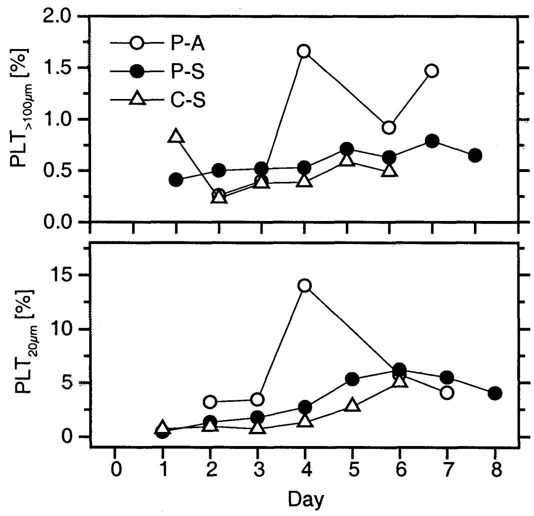

Figure 12. Daily $PLT_{>100\mu m}$ and $PLT_{20\mu m}$ of the bacterial pathway.
P-A: autumn P-mesocosm; P-S: spring P-mesocosm; and C-S: spring C-mesocosm.

Conclusion

In marine ecosystems in the estuary enclosed in mesocosms in the autumn of 1997 and spring of 1998, addition of phosphate reduced the N/P atomic ratios from 38 (autumn) and 94 (spring) to about 8. In the phosphate-enriched mesocosms, abundances of diatoms (*S. costatum*) and dinoflagellates (*P. dentatum*) increased, forming blooms in the autumn and spring, respectively. Such an increase in phytoplankton abundance was not observed in a control mesocosm in the spring. These results suggest that phytoplankton blooms may easily occur at the projected level of phosphorus loading in the estuarine ecosystem. In addition, such blooms may be not only of diatoms but also of dinoflagellates, despite the existence of high concentrations of silicate in the estuary.

Average rates of photosynthesis in the phosphate-enriched mesocosms in the autumn and spring were almost equivalent. Increments of biomass (POC) were also equivalent; about 1 mgC l^{-1} in both the autumn and spring P-mesocosms. The increase in POC amounted to twice the initial biomass in the mesocosms. Thus, phosphorus loading into this area of sea would cause an upsurge of biomass regardless of the differences in the seasons and/or dominant phytoplankton.

The characteristic response to the phosphate enrichment was different in each dominant phytoplankton type. *S. costatum,* which was dominant in the autumn, showed high Chl_*a*-specific photosynthesis activity immediately following the addition of phosphate, whereas the activity of *P. dentatum* in the spring reached its maximum a few days later. Consequently, in the autumn mesocosm, nitrate and silicate were almost completely exhausted within a few days, after which primary production was significantly reduced. On the other hand, primary production in the spring mesocosm increased gradually until the end of the experiment. Considering that there are various types of phosphate loading into the seawater mass (i.e., through rivers or elution from sediment), we assume that such a difference in characteristic response to the nutrient may be a factor regulating the dominant species of phytoplankton in this estuary.

The number of zooplankton increased with the phytoplankton blooms in the mesocosms. The tracer experiment with inorganic ^{13}C-bicarbonate revealed that copepods possessed the ability to ingest a considerable quantity of diatoms in the autumn mesocosm, whereas their ingestion of dinoflagellates was relatively lower. The standing stock of phytoplankton is generally controlled by the growth of the phytoplankton itself and removal of phytoplankton by grazers. Our results indicate that control of phytoplankton blooms through grazing by copepods is more effective for diatoms than for dinoflagellates. In the autumn mesocosm with the diatom bloom, the concentration of DOC increased and bacterial activity was enhanced more than in the spring. The other tracer experiment with ^{13}C-glucose demonstrated that a trophic pathway involving appendicularians as higher order consumers developed in the autumn mesocosm, suggesting that phosphate loading may indirectly affect the carbon cycle in the microbial loop.

Our mesocosm study is the first experiment to demonstrate that the biomass of an ecosystem in the Changjiang Estuary can readily increase with the addition of only phosphate. However, this experiment merely simulated one of the scenarios that will occur in the near future in the Changjiang Estuary, and more investigation needs to be done to predict the future change of marine environment in the estuary and the resulting ecosystem response.

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5.10 East Asian marginal seas: river-dominated ocean margin

G.H. Hong, J. Zhang., S.H. Kim, C.S. Chung and S.R. Yang

Abstract

The East Asian marginal region, composed of the Yellow Sea, East China Sea, and the East Sea (Sea of Japan) may be characterized as a river-dominated margin whose ocean processes are strongly influenced by riverine inputs. About 20% of the world's population resides in the watershed of the East Asian marginal seas. Therefore, the socio-economic drivers of nutrient, water and sediment fluxes in the drainage basins are significant enough to change the state of the seas and to feed back on human economic systems. Notable ones are the increase of nitrogen nutrients through river and atmosphere, reduction of riverine sediment transport to the seas and subsequent shift of nutrient regime from nitrogen-limited to silicate-limited in coastal water bodies as big as the Bohai. This nutrient regime shift results in harmful algal blooms (HABs) and leads to the destruction of marine aquaculture. The recent increase of precipitation during wet seasons lowers salinity enough to cause significant impact on local fisheries in Korea. The continued riverine silicate transport to the East Sea (Sea of Japan) in recent decades has caused the accumulation of silicate in the East Sea and make the sea as a silica ocean. Therefore, atmospheric CO_2 drawdown by biological pump seems to be working very efficiently in the East Sea. Additionally, the East Asian marginal seas are subject to the atmospheric transport of terrestrial materials due to persistent westerly winds and to the presence of arid zones in Siberia/Mongolia and northern China. Atmospheric dust is enriched with iron and gradually entrains nitrate and sulfate along its transport pathway. The Yellow Dust Storm events every spring appear to enhance primary productivity in the regional seas.

Introduction

East Asian marginal seas include the Yellow Sea, East China Sea, and the East Sea (Sea of Japan) and can be described as a river-dominated region whose ocean processes are strongly influenced by riverine inputs (Figure 1). Long-term salinity observations over the 30 years 1966-1995 in this region show a marked salinity lowering from June to August in the Yellow Sea and Cheju-Korea Strait region, and June to October in the East Sea (Figure 2) and large standard deviations in summer and late autumn in the region. The river-water input appears to continue until October in the south-western part of the East Sea due to the long distance transport (*ca.* 1,000 km from the mouth of the Changjiang) and the presence of persistent eddies in the region (Lie *et al.* 1995), after the cessation of the intensive rainfall period in the region (East Asian wet summer monsoon).

In general, rivers are major conduits for the transport of water, salt, organic matter and mineral matter from land to sea. Globally, large rivers may play a disproportionately important role in this terrestrial-marine linkage. The world's ten largest rivers transport approximately 40% of the freshwater and particulate materials entering the ocean (Milliman 1991). Smaller rivers may quantitatively be very important to global biogeochemical cycles but they function very differently in terms of material retention and transformation within the drainage basin and at the ocean margin interface. The magnitude of weathering and erosion processes on land, sediment storage within the river system and transport, transformation and burial processes in adjacent ocean margins collectively ensure that large rivers and their adjacent ocean environments are an important part of the global carbon cycle. RiOMars (River-dominated Ocean Margins) receive large inputs of terrestrial (allochthonous) organic carbon via rivers and marine (autochthonous) organic carbon resulting from high coastal productivity rates (McKee and Bianchi 2000). RiOMar environments represent the largest modern repository of particulate organic carbon. During interglacial times, approximately 80-85% of global carbon burial occurs in continental margins, primarily in RiOMar environments (Berner 1982). Terrestrial materials that are supplied to passive margins via rivers appear to be efficiently retained and processed within the margin environment. Annually, the total organic carbon burial in marine sediments is less than one-third of the riverine organic carbon discharge, indicating that riverine organic matter is rapidly mineralized. Organic carbon preservation (allochthonous and autochthonous) may not be as complete as previously thought for RiOMar environments (Hong, unpublished data). The high rates of remineralization and the great extent to which discharged riverine organic matter is remineralized in the coastal zone has only been appreciated in the last few years (Pernetta and Milliman 1995). The mechanisms to explain this phenomenon are presently unresolved.

In this paper, we review the socio-economic drivers of variation of water discharge, C, N, P, sediment fluxes at the catchment level of the Northeast Asian continent as well as the climate change and its effect on the receiving Northeast Asian marginal seas. Further we elucidate possible consequences to the human population in the region.

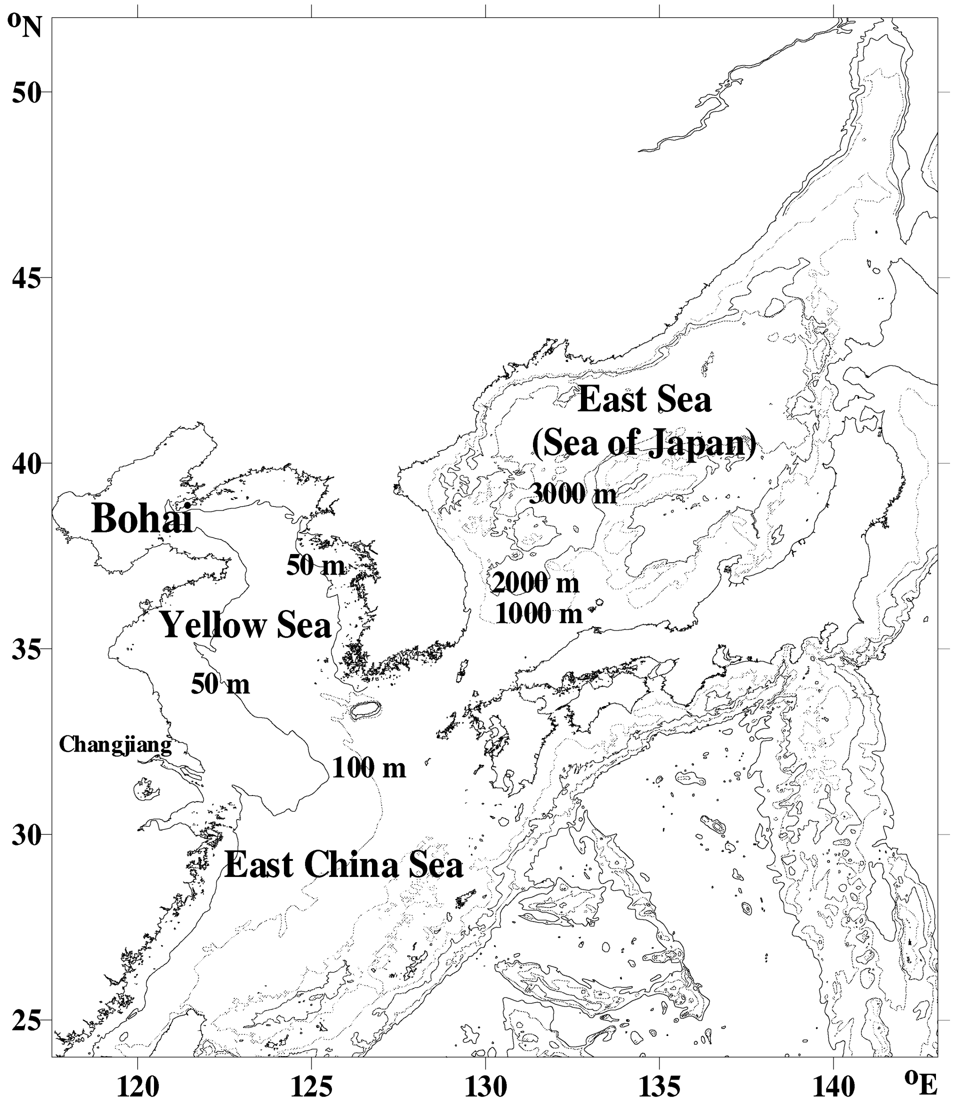


Figure 1. Marginal seas of the East Asia.

Regional setting

About 20% of the world's population resides in the East Asian continent. More specifically, 1.23×10^9 people live in China and 0.07×10^9 in the Korean peninsula (1998). As of 1999, the estimated population of Korea was 46.8×10^6 with a population density of 471 individuals km^{-2}, which ranks as one of the highest in the world (along with Bangladesh, the Netherlands and Belgium). Korea's annual population growth is 0.90% (1995), and her urbanization rate is 78.5% (1995). The amount of Chinese national waste drainage entering the seas exceed 6.5×10^6 t yr^{-1} in the 1990s, of which 80-90% was carried by rivers (Xu 1992, cited in Zhang *et al.* 1997). Economic losses related to waste drainage and pollution of the marine environment reached several billion yuans of RMB ($1.0 U.S. = 8.25 yuans of RMB). Hazards and catastrophic events, such as harmful algal blooms and reduced production of marine culture have been more serious in the 1990s compared with 10-20 years ago (Zhang *et al.* 1997). The Korean coast also receives as much as

867x10^6 m^3 of wastewater annually, and suffers from the frequent HABs. The frequency of red tide occurrence has increased since 1970s. The damage from HABs is estimated as high as 79,780x10^6 Wons ($1.0 U.S. = 1100 Wons) in 1995. Most damage was done to the cage fish culture and hanging oyster culture (Korean Ministry of Environment 1999).

1. Socio-economic drivers of change (e.g., C, N, P and sediment fluxes) at the catchment level

In the region, population increases in the recent decades in China and Korea requires more crop production, more industrial/urbanized land, and extensive application of fertilizers and pesticides.

1.1 Korea

In Korea, the total population of South and North Korea increased from 51.131x10^6 to 70.181x10^6 from 1975 to 1999, and 66.23% of the total population live in South Korea. Land use in South Korea may be summarized as 15,119 km^2 of urban and suburban area, 12,218 km^2 of farmland, and 65,325km^2 of forest in 1997 (Ministry of Environment 1997). The area of cultivated land has decreased from 2,298x10^3 to 1,924x10^3 ha (1 ha=10^4 m^2) from 1970 to 1997. Energy consumption has increased from 11.725 to 53.942x10^9 t of coal, 71.012 to 748.52x10^6 Bbl of petroleum, and fire wood and other energy sources from 14.668 to 1.344x10^6 t from 1971 to 1997 in South Korea. CO_2 emission increased from 146.092 to 218.325x10^6 t from 1981 to 1996, SO_2 decreased from 1.598 to 1.356x10^6 t from 1991 to 1997, NO_2 increased from 0.878 to 1.278x10^6 t from 1991 to 1997. Nitrogen fertilizer applied to the cropland was 481,524x10^3 t yr^{-1} from 1975 to 1997 and phosphorus fertilizer 237,637x10^3 t yr^{-1} between 1975 and 1997. Pesticides shipment has increased from 3,719 to 24,814x10^3 t from 1970 to 1997. The agricultural area specific application of N, P fertilizers and pesticides is 21,945 N t, 9,781 P t and 1.2 t of pesticides km^{-2} yr^{-1} (Korean Ministry of Environment 1999). However, the percentage of fertilizers and pesticides applied in the agricultural land and carried into the coastal ocean has not been quantified.

Water resources in South Korea are rather limited. South Korea gets an average of about 1,274 mm of rain annually, which is 30% more than the world average of 973 mm. It seems to be abundant, but due to the high population density, the average annual precipitation *per capita* is 2,755 m^3, or only 12% of the world average of 22,096 m^3. Since two-thirds of the annual precipitation falls between June and September, there are floods in summer and droughts in winter and spring. Tropical cyclones often invade the Korean Peninsula in July and August (Kim *et al.* 1998). These typhoons can bring significant amounts of water to the region averaging 13 mm h^{-1} (Bong 1996). Water resources in Korea largely depend on precipitation (126.7x10^9 m^3 of precipitation and 1.6x10^9 m^3 of groundwater). However, 57x10^9 m^3 (45%) of total precipitation is lost in the form of infiltration and evaporation, and about 69.7x10^9 m^3 (55%) is estimated to be annual surface runoff. Of this amount, 46.7x10^{9}m^3 (37%) is swept away by floods immediately after rainfall and the remaining 23x10^9 m^3 (23% of total precipitation) constitutes normal flow. Also, 30.1x10^9 m^3 (24% of total precipitation) are for municipal use (6.2x10^{9}m^3), industrial use (2.6x10^9 m^3), agricultural use (14.9x10^{9}m^3) and environmental use (6.4x10^9 m^3) annually. Daily water supply per person has increased from 256 l in 1980 to 309 l in 1994, and waste water discharge per person has increased from 180 to 314 liter per person daily in 1980 to 1993. Therefore, generation of domestic sewage has increased from 6.759x10^6 in 1980 to 15.976x10^6 m^3 day^{-1} in 1994. *Per capita* domestic water use is expected to rise from 409 l in 1997 to 480 l in 2011. Industrial water use is expected to increase from 2.6x10^9 m^3 in 1994 to 4.5x10^9 m^3 in 2011 (Korea Water Resources Corporation 2000). Municipal sewage is contaminated with domestic and industrial wastewater. Urbanization has increased from 68.7% in 1980 to 84.4% in 1994. Industrialization has been also rapid. Manufacturing industry has increased by a factor of 5 from 1981 to 1997. The industrial production index (total 10,000) was composed of mining (58.7), manufacturing (9,439.4), electricity and gas (501.9) in 1995. The overuse of fertilizers, pesticides and insecticides, and feces and urine of livestock in farming areas has led to serious pollution of rivers and streams nationwide, although these effects have not been quantified.

Shallow water aquaculture has doubled from 1978 to 1998 and its production was 777,230x10^3 t yr^{-1} in 1998 (Korean Ministry of Maritime Affairs and Fisheries 2000).

1.2 China

China is on the eastern side of the Euro-Asian sub-continent under the influence of East Asian Monsoons. Its total population was 5.7×10^8 in 1952 with the urban population accounting for 12.5%. In 1999, the total population was 1.2×10^9 with a natural growth rate of 8.8‰. The urban people increased to 30.9% of total population (National Bureau of Statistics 1998-1999). Most of the population lives in the eastern part of country, e.g., within 200 km of the coast.

Land use in China is diverse, including forest, grassland, cultural and undeveloped lands. Of the total area of 9.60×10^6 km^2, the cultivated area was 99.4×10^6 hectares (ha) in 1978, which reduced to 95.0×10^6 ha in 1998. The irrigated area for culture was 45.6×10^6 ha in 1978, and increased to 51.2×10^6 ha in 1997. Energy consumption amounted to 1.42×10^9 t of Standard Coal Equivalent (SCE) in 1997, as compared to 96.4×10^6 t in 1957. 1,000 kWh is equivalent to 1.229 tonnes of SCE. Of the energy consumption in 1997, coal represents 73.5%, petroleum 18.6%, natural gas 2.2% and hydropower accounts for 5.7% (State Statistical Bureau 1998). In 1980, hydropower production was 58.2×10^9 kWh, which increased to 188×10^9 kWh in 1996.

The climate of China covers a wide range from arid-temperate to humid tropical zones. The annual average temperature ranges from 5 °C in the north to 25 °C in the south of country. Rainfall is 100-200 mm yr^{-1} in the north-west inland region and reaches 1,500-2,000 mm yr^{-1} along the south-east coasts, with annual rainfall up to 4,000 mm yr^{-1} on tropical islands. The humid climate zone in China accounts for 32% of surface area, the arid zone for 31%, with other regions at intermediate positions. Owing to high altitude of Qinghai-Tibet Plateau, China has high mountains in the west and low alluvial plains in the coast area. Large rivers in China rise in the west and north-west and flow east and/or south-east, emptying into the Pacific and Indian oceans. The total surface water volume in China is *ca.* 3.0×10^{12} m^3, with surface runoff of 2.7×10^{12} m^3 yr^{-1} (State Statistics Bureau 1997-1998). Flow rate of rivers varies through the year; water discharge in the flood season may account for 70-80% of the total annual load.

The total crop production of country was 4.42×10^8 t in 1992, 4.94×10^8 t in 1997 and 5.1×10^8 t in 1999 (National Bureau of Statistics 1999-2000). The application of chemical fertilizers increased from 8.84×10^6 t in 1978 to 39.8×10^6 t in 1997, of which the nitrogen fertilizer comprises 21.7×10^6 t, phosphorus fertilizer 6.98×10^6 t, potassium fertilizer 3.22×10^6 t and compound fertilizer 7.98×10^6 t (State Statistical Bureau 1997-1998). Accordingly, the rivers in the country may have high levels of nutrients. For example, the DIN concentration of the Changjiang and Huanghe has doubled in last two-three decades, and reached ~100 μM in 1990s (Zhang *et al.* 1995, 1999). Wastewater from industry was 23.5×10^9 t in 1991, with 63.5% pretreated before drainage. In 1997 the industrial wastewater drainage was reduced to 18.8×10^9 t, and 84.7% of this wastewater was pretreated before discharge (State Statistical Bureau 1998).

The coastal area of China amounts to 28×10^4 km^2, plus 2.1×10^4 km^2 of beach area. Shallow water culture area is 71.6×10^4 ha, that of beach-area is 55.6×10^4 ha. Moreover, the area of fishing grounds on the adjacent continental shelf is 2.8×10^8 ha, of which the Bohai accounts for 7.7×10^6 ha, the Yellow Sea 35.3×10^6 ha, the East China Sea 54.9×10^6 ha, and the South China Sea 182.1×10^6 ha (State Statistics Bureau 1997-1998).

2. Identification of key pressures on the system

2.1 Chinese rivers

The Yellow River (Huanghe) is currently the second largest river in the world in terms of sediment load into the sea. Yang *et al.* (1998) reviewed the human impact on the Yellow River. According to that study, the Yellow River had 10% of the present level of suspended sediment and channel shifts were very rare until 3000 years before present (BP). From 800 years BP it became very turbid due to the cultivation of the Loess Plateau. Initially, the Yellow River discharged into the Bohai Sea and the sediment from the Yellow River was indirectly transported to the Yellow Sea through the Bohai Strait. At that time, less than 1% of the river discharge of suspended sediment was transported into the Yellow Sea. However, in 1126 AD the river course shifted into the Yellow Sea because the southern side of the river embankment in Kaifeng City was removed to keeping the cavalry troops of Jin State from entering the China, and since then the Yellow River has discharged its sediment directly into the Yellow Sea. In 1855, the Yellow River changed its course to the north and discharged into the Bohai again. The present sediment source of Yellow Sea since 1855 is the abandoned Old Yellow River Delta off the northern Jiangsu coast. The ever-increasing population and agricultural activities has demanded more water resources, leading to the construction of 18 dams along the river path and this modification of the river course decreased freshwater discharge significantly. The no-water discharge days have increased from 12 to 133 days a year from 1972 to 1996 (Yang *et al.* 1998). Water discharges decreased from 47.2 to 17.0 $x10^9$ m^3 yr^{-1}, and sediment load decreased from 1.20 to $0.41x10^9$ t yr^{-1} (11 years average 1953-1963 and 7 year average 1986-1992) at Lijin hydrographic station (Yang *et al.* 1998).

The Changjiang is the fourth largest river in the world in terms of water flow (30,000 m^3 s^{-1}) and sediment load ($500x10^6$ t yr^{-1}), with large inter-annual variations (Shen *et al.* 1998). A number of natural lakes, e.g., Dongtinghu and Poyanghu along the Changjiang, have a profound effect on both water and sediment discharge into the East China Sea (Shi *et al.* 1985). Large reservoirs were built in 1968 (Danjiangkou Dam), 1981 (Gezhou Dam) and begun in 1997 (Three Gorges Dam). Work for the diversion of water from the lower Changjiang to North China under consideration would divert 1,000 m^3 s^{-1} of water from the lower Changjiang to North China (Shi *et al.* 1985). The construction of those dams inevitably reduced sediment transport to downstream. Due to the building of Danjiangkou reservoir in 1968, annual suspended sediment discharge was reduced from 100 to $1.3x10^6$ t yr^{-1}, a reduction of 99%. Deforestation in Sichuan has occurring since 1954 and only 13% of the surface area of Sichuan was still under forest in 1978. Therefore, sediment yields in the three northern tributaries of Sichuan were very high due to serious soil erosion (Shi *et al.* 1985). Therefore, the sediment dynamics of the Changjiang River estuary and adjacent shelf must be considerably affected by these reservoirs.

Historically, the Huaihe discharges into the Yellow Sea with an amount of $53\text{-}700x10^8$ m^3 yr^{-1} of water. Over the drainage basin, rainfall in June to September accounts for 60-70% of annual precipitation and summer floods cause economic damage and deaths. The Yellow River took the course of the Huaihe in 1194-1855, i.e., over a period of *ca.* 661 years, leaving a huge abandoned delta region on the western coast of the Yellow Sea. In this period, the riverbed was several meters higher than the fluvial plains and the coastline moved seawards by 60 km. Over the watersheds, the cultivated land is $13.3x10^4$ km^2 with a population of $1.3x10^8$. About 35 large and 150 middle-sized reservoirs were constructed along the river course in last 50 years, with a total capacity of $25.0x10^9$ m^3. Today, the Huaihe discharges into Hongzehu and the Jing-Hang Grand Canal, and hence its water flow into the Yellow Sea is quite limited (Committee of Geographic Glossary in China 1996).

The Minjiang takes its water source from the Wuyishan in south-east China. Its drainage area is essentially in the subtropical monsoon area. The rainfall in this region is 1,500-2,500 mm yr^{-1}, with a mean runoff of 1,022 mm. In the lower reaches, the ratio between maximal to minimal water flow is 3.1, and the river flow in April–September is 80% of annual discharge. The record flood flow was $29.4x10^3$ m^3 s^{-1} in 1968. The vegetation over the watersheds is well developed and the river TSM is 50-100 mg l^{-1} (Xiong *et al.* 1989). In the Minjiang drainage basin, cultivated land is $55x10^4$ ha, with irrigated area $38x10^4$ ha and forestland $350x10^4$ ha. About 150-200 hydropower stations have been constructed over the drainage basin (Xiong *et al.* 1989).

The Yalujiang forms the border between China and North Korea. Zhang *et al.* (1998) reviewed the chemistry of the Yalujiang recently and found that the long-term average water discharge is 1200 m^3 s^{-1}. Four dams and reservoirs have been constructed since 1941 (Soo Pung Dam) for water management and electrical power production in the last forty years. Due to the dams, the riverine sediment load is rather limited, averaging *ca.* 5 $x10^6$ t yr^{-1} and suspended matter concentrations can be as low as 5-10 mg l^{-1}. The lower reaches of the river receive a considerable amount of wastes from both non-point (e.g., agriculture) and point (e.g., domestic and industrial) sources. Major cities of Dandong and Sinuiju, close to the river mouth, discharge waste water amounts as high as $1x10^6$ t yr^{-1}, and high nutrient concentrations (e.g., 900 μM of NO_3^-) have been found in the river (Zhang *et al.* 1998).

2.2 Korean rivers

The climate of Korea is suitable for conifer and deciduous forests, though the relatively unequal distribution of rains has not allowed very dense vegetation. At present, good forests can be found in mountain areas, where the forests have been protected and managed, especially since the '60s. Major characteristics of rivers in Korea are:

(1) The river reaches are relatively short and channel slopes are relatively steep. Drainage areas are small in Korea compared with other major continental rivers. Channel slopes are relatively steep in the upper reaches because of steep mountains and deep valleys in the uplands.
(2) Flooding occurs quickly and peak flood discharges are enormous. Due to the topography and torrential rainfall, the hydrological flow patterns of rivers in Korea are very sharp and peak flood discharges are enormous compared with other comparable rivers in the continent.
(3) Flow variations are high. The coefficients of the river regime, expressed by maximum discharge over minimum discharge for rivers, usually range from 300 (the Keum River) to 400 (the Han River) and 500 (the Yeongsan River). This large variation in the flow discharge causes serious problems for river management, flood control and water use. This river regime coefficient is 22 in the Changjiang and >200 in the Huanghe (Korea Water Resources Corporation 2000).

Relatively long rivers with complicated dendritic drainage patterns flow westward into the Yellow Sea. Representatives are Aprock (Yalujiang, 790 km), Chongchon (199 km), Taedong (439 km), Han (514 km), Kum (401 km) and Yeongsan (116 km). The Somjin and Nakdong rivers only flow south. Alluvial plains have developed along these rivers, partitioned by ramified mountain ranges of the Sinian and Liaodong direction. They occupy rather small and narrow areas, but occasionally coalesce to form broad plains, typically close to coastal regions (Lee 1987). Due to the steep slope in the upper reaches, and high river regime coefficient, the sediment yields are relatively high (Table 1), averaging 413$\pm$33 t km^{-2} yr^{-1} over the whole watersheds for the rivers flowing into the Yellow Sea.

Table 1. Characteristics of water discharge and sediment yield of some rivers emptying into the Northeast Asian Coastal Ocean from the contiguous continent.

River	Length	Drainage basin	Water discharge	Sediment discharge	Sediment yield
	km	km^2	10^9m^3 yr^{-1}	10^6 t yr^{-1}	t km^{-2} yr^{-1}
Han	469.7	2,6218.9	20.9	12.42	474
Keum	401.4	9,885.80	5.8	3.95	400
Yeongsan	115.8	2,798.2	2.1	1.24	443
Anseong	76.2	1,722.0	1.1	0.67	389
Sapkyo	65	1,670.6	1.2	0.65	389
Mankyong	98.5	1,601.7	1.1	0.64	400
Dongjin	44.7	1,034.0	0.7	0.41	397
Seomjin	225.3	4,896.5	3.2	3.13	639
Nakgdong	525.7	23,859.3	9.2	12.1	507
Huanghe (1953-1963)	5400	745x10^3	47.2	1100	1610
Huanghe (1986-1992)			17.0	410	550
Changjiang	6300	1,950x10^3	895.6	500	241
Huaihe	1000	27x10^4	25.7		
Minjiang	577	61x10^3	62.4	8.74	
Aprock (Yalujiang)		62630	37.8	4.8	77

Large dams have been constructed in Korean rivers since 1943 to provide water for urban areas, agriculture and electricity generation. Most large rivers in Korea have at least one dam along the course of river. These dams significantly reduce the magnitude of variability of river water and sediment discharge. Storage of water for months in the deep dams leads to the development of anoxic/suboxic environment in the bottom water and hence changes the contents of redox-sensitive chemical elements in water and in suspended particulate matter in the river. A comparative study on the chemistry of inflowing and outflowing water of Lake Soyang in the upper reaches of the Han River (Hong *et al.* 1989a) found that the concentration of suspended particulate matter was lower in the outflowing water than in the incoming water, although the outflowing water channel is located 30 m below the top of the dam. Manganese enrichment over iron was observed in the outflowing waters especially during the dry season. Thus Lake Soyang provides a differential trap for iron and manganese, preferentially holding iron and removing manganese through redox reactions (Hong *et al.* 1989a). Since manganese oxide is utilized before iron oxide as an electron acceptor after dissolved oxygen and nitrate are consumed in the oxidation of reduced carbon, manganese oxide is mobilized as soluble Mn^{2+} from the lake bottom sediment. The bottom water of the lake is suboxic/anoxic for the thermally stratified period. Oxidation of Mn^{2+} takes several days while oxidation of Fe^{2+} takes a few seconds, so that Mn^{2+} can stay much longer than Fe^{2+} in the lake water column and leave the lake. There must also be significant uptake of nutrients in the euphotic layer of the lake and subsequent retention in the deep water of the lake. The large amount (170 g C m^{-2} yr^{-1}) of organic matter production in the epilimnion is largely responsible for oxygen depletion in the hypolimnion for the much of the year (Hong *et al.*, 1989b). Therefore, nutrient flux to the downstream decreases accordingly.

On the Han River, 7 dams were constructed, from the Chungpyung Dam in 1943 to the Chungchu Dam in 1986. In small rivers, estuary dykes have been built to obtain water for irrigating agricultural land around the lower reaches of the rivers. The estuary dykes of the Keum, Anseoung, Sapkyo and Yeongsan rivers were built in 1990, 1973, 1979, and 1981 respectively.

Little is known about the changes to water chemistry and hydrology after river barrage construction in Korea. In the Keum River estuary dyke, nutrient concentrations have increased by a factor of 2-7 after the river barrage completed, from 2-17 $\mu g\ l^{-1}$ of NH_4^+, 1-2 $\mu g\ l^{-1}$ of NO_2^-, 20-100 $\mu g\ l^{-1}$ of NO_3^- before the river barrage construction to 15-30 $\mu g\ l^{-1}$ of NH_4^+, 2-4 $\mu g\ l^{-1}$ of NO_2^-, and 60-120 $\mu g\ l^{-1}$ of NO_3^- after the river barrage construction (Yang *et al.* 1999).

2.3 Atmospheric input in the Yellow Sea

The atmospheric pathway is a significant conduit for the transport of terrestrial material to the sea in East Asian seas due to the persistent westerly wind and the arid Gobi Desert and the Loess region in the East Asia. In the Yellow Sea proper, the average sediment accumulation rate is *ca.* 250 g m^{-2} yr^{-1}, of which 50 g m^{-2} yr^{-1} is delivered through the atmosphere (Zhang *et al.* 1993). In the more remote East Sea (Sea of Japan), atmospheric dust flux is estimated to be 10 g m^{-2} yr^{-1}. River input is mostly confined to the river mouth and estuarine area, but atmospheric input is effected over the entire sea, especially the Yellow Sea and East Sea proper which are away from the direct influence of the rivers. Preliminary shipboard measurements suggest that atmospheric inputs account for over 90% of the some trace metals to the Yellow Sea (Hong *et al.* 1998). Also, high aerosol nitrate concentrations were usually associated with the Yellow Dust storms at the land-based stations in Korea. The mean concentration of aerosol nitrate was 114 $\pm$86 nmol m^{-3} in November 1997 and 144$\pm$70 nmol m^{-3} in April 1998. The sampling period of April 1998 corresponded to the Yellow Dust storm period. Due to the selective use of lower S-containing fuels in the region, atmospheric aerosol nitrate concentration are expected to increase continuously in the near future (Korean Ministry of Environment 1999).

3. State Changes in the receiving marine environments

3.1 Change in nutrient flux

The ratios of nitrogen, phosphorus and silicon in the coastal ocean have changed due to human impacts in the watershed. In general, nitrogen and phosphorus had been discharged in sewage, but nitrogen became enriched in sewage after the 1970s when phosphorus-free detergents became available. Phosphorus is more resistant than nitrogen to weathering. In the phytoplankton-based system (i.e., autotrophic), diatoms are the preferred phytoplankton species for commercial resources. Diatoms have a silicon skeleton, and hence populations dominated by diatoms need a supply of silicon if they are to produce new cells. Diatoms use silicate more rapidly than nitrate and silicate is a potentially limiting factor in the sea area of this region. Compared with nitrogen, silicon appeared to be regenerated much more slowly in oceanic waters (Dugdale 1972). The available data suggest that silicon limitation on nitrogen uptake needs to be closely investigated. Silicate depletion relative to nitrogen has been observed in many coastal waters in Korea (Pae and Yoo 1991). The dominant phytoplankton species group has shifted from diatoms to flagellates, and harmful algal blooms have occurred more frequently in recent decades. A large water body in the East Asian marginal seas, the Bohai Sea (ca. 550x300 km), has also shown a similar phenomenon of relative silicate depletion. In the Bohai, both concentration and the elemental ratios among nutrients have changed dramatically over the last 20 years, probably due to the decrease of Yellow River sediment and water discharges. The increase of nitrogen and decrease of phosphate and silicate has led to an increase in the N/P ratio and a decrease in the Si/N ratio. The previous nitrogen limitation has been switched to a phosphate and silica-limiting environment. This limits diatom growth and promotes the development of pyrrophyta HABs in the Bohai (Yu *et al.* 1999).

3.2 Primary productivity regime of the Yellow Sea

Comprehensive understanding of the nature of primary productivity in the sea is essential for the sound management of marine resources. However, the controlling factors on primary productivity are little understood in the East Asian marginal seas. Recently major field measurements on new and regenerated primary production were undertaken for the Yellow Sea (Yang *et al.* 1999a). Regenerated primary production comprises more than 60% of the primary production in the Yellow Sea. The overall dominance of ammonium utilization by phytoplankton appears to have resulted from the consistent preference for ammonium and the presence of higher affinity, higher capacity uptake system for ammonium than nitrate. In the coastal region inside the tidal front, both new and regenerated production are high, whereas in the Yellow Sea proper, both new and regenerated production are low (Yang *et al.* 1999a). The Yellow Sea proper is always oligotrophic due to the lack of nutrients for the year except during winter (Chung *et al.* 1999). Therefore, the Yellow Sea is very fragile/sensitive to external forcing, wind and atmospheric inputs. The effects of storms which mix the water column to provide new nutrients in the upper euphotic layer and hence to lead phytoplankton blooms have not been addressed in the Yellow Sea, but a three or four day cycle of atmospheric pressure change is expected to induce phytoplankton blooms in the Yellow Sea proper as modelled by Bissett *et al.* (1994) in another oligotrophic ocean. A significant amount of nitrate is loaded in aerosols, Yellow Dust storm events and concurrent HABs in the Yellow Sea proper (Zhang and Liu 1994; Zhang 1994).

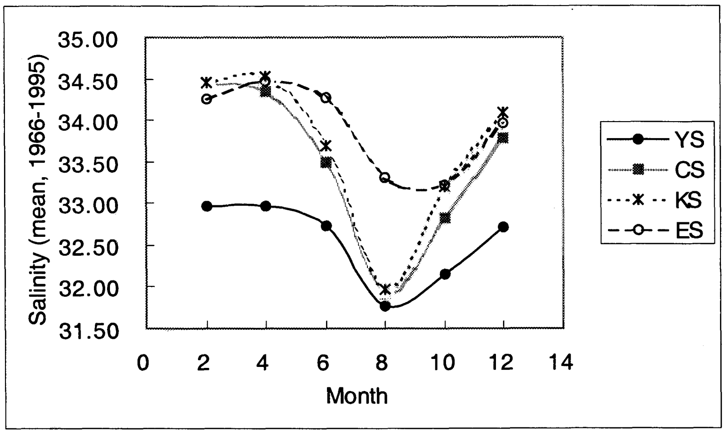
3.3 Changes in sediment accumulation in the sea bottom due to changes in river course in the Yellow Sea

In the bottom of the East Asian seas, sediment accumulation has reflected the change of sediment supply from rivers. Sediment discharge from rivers has decreased due to the construction of dams along the river course and increase in water demand in the drainage basins on the East Asian continent. For example, the Yellow Sea undergoes a substantial change in the sediment accumulation on the sea floor. The ^{210}Pb-derived sediment accumulation rates are 28 to 72 mg cm^{-2} yr^{-1} (0.02 to 0.03 cm yr^{-1}) in the distal bottomset deposits of subaqueous Yellow River delta and 772 mg cm^{-2}yr^{-1} (0.57 cm yr^{-1}) off the Jiangsu coast (Hong, unpublished data). Accumulation rates in the Central Yellow Sea (distal bottomset deposits of subaqueous Yellow River delta) increase from 0.03 cm yr^{-1} (20 mg cm^{-2} yr^{-1}) to 0.27 cm yr^{-1} (220 mg cm^{-2} yr^{-1}) from east to west across the Central Yellow Sea (Alexander *et al.* 1991). High sedimentation rates were observed off the Jiangsu coast (0.4 cm yr^{-1}, estimated from the depth distribution of excess ^{210}Pb from Nagaya and Nakamura 1992). Much higher sedimentation rates off the Yangtze River (5.4 cm yr^{-1}) were found by DeMaster *et al.* (1985). Excess ^{210}Pb down core distributions suggest that the surface of the mud deposit is contemporaneous. Sediments are transported from north to south-east along the Chinese coast, especially during winter storm periods (Milliman *et al.* 1985). In the eastern part of the Central Yellow Sea, an abrupt slowdown of sedimentation rates appears to have occurred approximately 60-80 years ago, declining from 168 mg cm^{-2} yr^{-1} (0.11 cm yr^{-1}) to 59 mg cm^{-2} yr^{-1}(0.04 cm yr^{-1}) and 248 mg cm^{-2} yr^{-1} (0.34 cm yr^{-1}) to 28 mg cm^{-2} yr^{-1} (0.04 cm yr^{-1}) at stations Y9107-11 and Y9111-05, respectively (Hong, unpublished data). The Yellow River mouth shifted from south of the Sandong Peninsula (Yellow Sea) to north of the peninsula (i.e., the Bohai) in 1855. Although ^{210}Pb derived sediment age has a large uncertainty due to slow sediment accumulation, the recent decrease in sediment accumulation rate corresponds to the decrease of sediment supply from the old Yellow River delta and Bohai. The annual sediment discharge of the Huanghe (Yellow River) decreased from ca. $1.1x10^9$ t yr^{-1} in 1950 to ca. $0.7x10^9$ t yr^{-1} after 1970 due to the construction of dams (Yang *et al.* 1998). More than 90% of the Huanghe sediment load is deposited in the lower reaches of the river and within the estuarine area. Therefore the actual sediment flux to the Yellow Sea is very limited and may take place via a nepheloid layer across the Bohai Strait which would transport ca. $6x10^6$ t yr^{-1}, i.e., less than 1% of the Huanghe sediment discharge (Martin *et al.* 1993). Sediment supply from the Korean Peninsula to the central basin around stations of Y9107-11 and Y91111-05 is not likely to be significant (Chough and Kim 1981; Alexander *et al*, 1991). The impact of sediment accumulation rate change on the benthic biota is not available for the Yellow Sea.

3.4 Changes in salinity in the surface water due to the flooding of rivers

Due to the large freshwater discharge from rivers into the East Asian marginal seas, the seas have been subjected to significant lowering of salinity (more than 1 salinity unit) every summer depending upon the magnitude of precipitation (Figure 2). In the area off Cheju Island, salinity dropped as much as 6 psu from the normal value in early August 1998, which cause a significant mass mortality of oyster and abalone in the aquaculture area (Joongang Daily, 6 August 1998). Construction of barrage at the lower river course also significantly modifies the previous salinity regime near the river mouths. A few examples are given here.

(A)



(B)

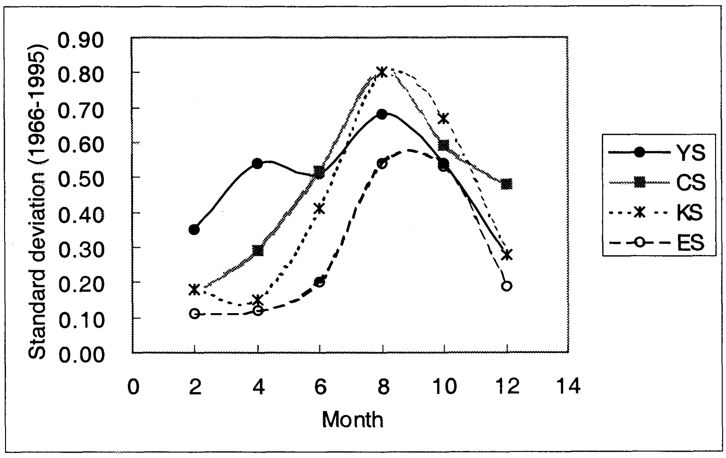


Figure 2. Seasonal salinity change (A) and standard deviation of salinity (B) in the Northeast Asian marginal seas of the Yellow Sea, northern part of the East China Sea, and southwestern part of the East Sea (Sea of Japan). Data from Korean National Fisheries and Development Institute. YS, CS, KS and ES represent the observation station of the central Yellow Sea (311-10, 34°43'N 124°23'E), middle of Cheju-Korea Straits (205-03, 34°06'N 127°57'E), Korea Strait (207-03, 34°54'N 129°15'E), and the East Sea (104-10, 37°03'N 130°55'E), respectively.

3.4.1 Keum River barrage

Freshwater discharge was as high as 156 $m^3 s^{-1}$ before the river barrage was built in 1994. During the summer when heavy rainfall occurs, the riverine freshwater propagated to the west as far as 10 km and to the north as far as 50 km (Seung *et al.* 1990). After the barrage construction in 1994, the freshwater discharges from the barrage only during the normal flow period. During heavy rains, the water gate is opened in order to prevent flooding in the watershed. For example, $1.5x10^9$ m^3 of water was discharged into the Yellow Sea during the period of 1 to 12 July 1997. As result, a 5-6 m thick low-salinity (less than 30 psu) plume was distributed over the large area between the Keum River and Ochong Island, up to 100 km off the river mouth. Even if the total freshwater discharge is the same before and after the barrage construction, freshwater discharge rate per unit time has increased. Thus, vertical mixing due to tide and wind is suppressed, the river plume is stronger and vertical distribution of water density is more pronounced than before the barrage construction. Consequently, the river plume spreads over a much wider area and more rapidly (Choi *et al.* 1999). The ecological consequences of lowering salinity in the region have not been studied.

3.4.2 Changjiang effluent plume

The Changjiang effluent plume significantly modifies the salinity field in the East Asian marginal seas. In the Yellow Sea, the CTD data obtained reveal a well-posed historical annual cycle for distribution of low salinity water in summer. There are five major water masses in the Yellow Sea: Yellow Sea Warm Current Water (YSWCW), Yellow Sea Bottom Cold Water (YSBCW), Korea Coastal Water (KCW), China Coastal Water (CCW) and Changjiang Diluted Water (CDW). In summer, a low salinity core is formed in the surface 20 m depth in the southern Yellow Sea since the trapped CCW and CRDW are piled up to the west of Cheju Island. This low salinity core water drifts eastward as a single body to adjust the basin-scale pressure fields (Lee *et al.* 1999). Water residence time was calculated to be 5.6 years in the Yellow Sea using salinity, river discharge rate, precipitation, and evaporation data over the Yellow Sea, and freshwater input from the Changjiang dominates the water budget in the Yellow Sea Lee *et al.*1999). Three major factors are involved: the amount of discharge from the Changjiang to the Yellow Sea, salinity difference between the Yellow Sea and East China Sea, and the problem of single box model for the riverine input dominated system. Liu *et al.* (2000) estimated the Changjiang input into the Yellow Sea to be 14.1% ($130x10^9$ m^3) of the annual freshwater discharge, assuming average surface mixed layer is 10 m and using monthly salinity data. This amount alone is by far the largest freshwater source in the Yellow Sea, the Cheju-Korea Straits region and the Uleung Basin in the East Sea (Sea of Japan) (Figure 2).

4. Critical or threshold characteristics of material fluxes, highlighting their link to pressures in the catchment areas and how change in the coastal zone may feed back on the human system

4.1 Nutrient fluxes from land to ocean via ocean currents

The fluxes and distribution of nutrients are determined by strong seasonal variation of wind and precipitation since the region is under the influence of East Asian Monsoon. The Cheju Current and the Tsushima Current are two major material and nutrient streams in the East Asian marginal seas. The Cheju Current carries water from the Yellow Sea and East China Sea to the East Sea (Sea of Japan) via the Cheju Strait. The Tsushima Current carries the Kuroshio water to the East Sea via the Korea Strait. In the wet monsoon period every year, significant amounts of freshwater, nutrients and other land-derived material from the Chinese continent discharges to the west of Cheju Island via the Changjiang. Korean rivers discharge their material into the western and southern coastal waters. This is later entrained by the Cheju Current (0.37 to 0.58 sv with maximum speed of 15 to 20 cm s^{-1}) and further moved to the Cheju-Korea Straits (Suk *et al.* 1996). Thus the Cheju Current forms a strong nutrient pathway in the East Asian marginal seas (Chung *et al.* 2000), which eventually feeds the East Sea (Sea of Japan). Nutrient fluxes through the Cheju Strait are 2-3 times higher than those of Tsushima Current between Cheu and Kyushu islands, and comparable to that of the Kuroshio off Taiwan (Hong 1999).

Annual precipitation has increased in recent decades along the southern coasts of Korea and Cheju Island. Monthly mean precipitation data are available for Pusan and Mokpo since 1910, for Cheju since the late 1920s, for Yosu since late 1940 and for Sogipo since 1960 (Hong 1999). The interannual variability was observed with a quasi-period of 2 to 7 years relative to El Nino periods and a longer time-scale (interdecadal) fluctuation, especially in Cheju. The linear increasing trend of precipitation is about +7 mm per 10 years in Pusan and Mokpo, +16 mm per 10 years in Cheju, and much higher in Yosu (+40 mm per 10years) and in Sogipo (+80 mm per 10years) where the total precipitation is the highest in Korea. This recent increase in precipitation leads to an increased erosion rate of the land surface, hence increase the material export from the land to the sea.

The hydrographic records of greater China go back to the late 19th Century. Water discharge of the Changjiang has been measured since 1865, and the annual maximal water discharge at lower reaches show a rising trend (Zong and Chen 2000). Human activities over the drainage basin have considerably reduced water quality, flood storage and drainage capacity of landscapes, deforestation and pollution.

The increased influx of nutrients, especially silicate, has a major impact on the chemistry of the East Sea (Sea of Japan). Numerous examples reveal that the oceanic environment is changing due to either natural or man-made variations in climate and river runoff (Chen *et al.* 1999). The East Sea (Sea of Japan) is a deep basin with restricted connection to the open ocean. The surface area of the East Sea is 1×10^6 km^2, an average depth of 1,350 m and a maximum depth of over 3,500 m. The deepest strait connecting it to the open ocean is the Korea and Tsugaru Strait which is only 135 m deep. It is generally believed that subsurface waters are formed in the northern East Sea (Japan Basin) by downwelling at the periphery of a cyclonic gyre and through vertical convection in the winter. These processes result in a vertical homogeneity of deep waters with an anomalous high concentration of dissolved oxygen throughout. 84% of the seawater volume has a temperature of 0-1°C and salinity of 33.96-34.14 psu. The bottom layer, below 2,000 m, is even more homogenous. This almost totally isolated, relatively homogeneous body of seawater is ideal to observe temporal changes. The East Sea has experienced fluctuations in bottom-water properties over many time scales. These include increases in temperature and decreases in thickness of the bottom boundary layer and oxygen concentrations. Such temporal variations were thought to be transient and probably caused by a recent reduction or cessation of new bottom-water formation in the northern East Sea. Such an event occurred during the last glacial period when the East Sea became anoxic, and it did not become oxic again until early in the Holocene. An apparent stagnation started around 1950 and is still going on. The water temperature increase is consistent with heat flow data (Chen *et al.* 1999).

We have determined lithogenic and biogenic silicon (Si) contents in the suspended particulate matter in the East Sea. Biogenic Si concentration varied from 1.0 to 20.0 $\mu g\ l^{-1}$ in the northern Japan Basin and 2.4 to 25.3 $\mu g\ l^{-1}$ in the southern Uleung Basin (i.e., higher in Uleung Basin than in the Japan Basin). Particulate biogenic Si concentration decreases exponentially with depth and dissolution rate similarly in both basins. Depth distribution of dissolved Si concentration in the upper 2,000 m are also very similar in the two basins. Dissolved oxygen decreased with time in deep water, while dissolved Si concentration increased with time. Based on the measurement of KH-77 St. 24, dissolved Si concentration has increased about 15% between 1977 and 1981 (Horibe 1981; Kim SH, unpublished data). Therefore, Si production must have increased in the recent decades. The mode of Si delivery to the East Sea is probably particulate, because dissolved nutrients are depleted and suspended particulate matter is enriched in the surface water of the southern Yellow Sea, the Cheju-Korea Straits and the East Sea (Sea of Japan). The year-long sediment trap study also showed that the majority of sinking particles are silica and lithogenic matter (Hong *et al.* 1997), so the East Sea may be regarded as a silica ocean, which more effectively removes atmospheric CO_2 than does the carbonate ocean (Honjo 1997).

4.2 Three Gorges Dam in the Changjiang and primary productivity in the East China Sea

Many marine state changes are expected to occur due to the completion of the Three Gorges Dam in the course of the Changjiang, such as change in water regime, reduction of nutrients and sediment into the estuary. Chen (2000) calculated nutrients budgets in the East China Sea (ECS), and estimated that total riverine input of P amounts to only a small fraction of the external P supply to the ECS. While a reduction of P flowing out of the Changjiang is not very significant, the fact that the completion of the dam will affect the fresh water supply to the ECS is very critical. It is not yet known how much the Three Gorges Dam will reduce the Changjiang sediment load. Cutting back the Changjiang outflow by a mere 10% would reduce the cross-shelf water exchange by roughly 9% based on the water and salt balances. In that case, the on-shore nutrient intrusion would also be reduced by that much. This means that whole ecosystem in the ECS would be modified the food-web proportionately (Zhang *et al.* 1999).

5. Conclusions

Major findings in this work are:

1. River supply of water, sediment, and nutrients fluxes into the coastal ocean in the East Asia have been significantly modified due to dam construction, diversion of water courses and contamination by sewage input arising from the large population in the drainage basins.

2. Elemental ratios among nutrient species have been shifted from nitrogen-limiting to silicate-limiting conditions, and consequently harmful algal blooms occur more frequently in the recent decades in the receiving coastal ocean.

3. Atmospheric nutrient flux to the sea is enough to induce phytoplankton blooms in the oligotrophic shelf seas, because the region is under the influence of Asian dust storms.

4. Reduction of riverine sediment flux to the sea has been shown to change the sediment accumulation rate in the Yellow Sea proper in the past century.

5. Changjiang discharge into the seas causes ecological disturbance in the region directly, by lowering salinity.

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5.11 Impacts of anthropogenic activity on the quality of the coastal zone environment in the Sea of Japan

V. V. Anikiev

Introduction

In recent years Russia has been intensively assimilating the natural marine resources of its Far East.

The most important of these resources are iterated biological resources that ensure 70% of the fish diet for the population of Russia and serve as a source of valuable seafood such as crabs, sea cucumbers (trepangs) and salmon for Japan, Korea and China. Thus, the deterioration of the marine environment in the coastal zone and on the shelf can cause social risks not only in Russia, but also in the adjacent countries, and will lead to a degradation of fishing as a branch of the economy. Hence, special attention is paid to the trends of change in coastal zone quality caused by various anthropogenic factors or their combinations.

The following study has been carried out over the last 10 years aimed at the solution of the above problems:

1) Origin of the spatial and temporal dependence of ecological risk in the Sea of Japan along the Vladivostok - Niigata cross-section;

2) Assessment of the ecological damage due to wastewater drainage into the coastal zone and chemical weapons into the shelf zone of the Sea of Japan.

Choice of measure of change in the quality of the environment

Two parameters were used as measures of anthropogenic influence on environmental quality in the coastal zone of the region:

1) ecological risk, i.e. the probability of death of biota and population;
2) ecological damage that shows economic loss due to the deterioration of natural resources.

This choice is stipulated by the situation that is typical not only of Russia, but also of other states where the existing official system of environmental quality assessment does not meet modern requirements.

The basic environmental quality standard currently used in Russia and abroad is the maximum permissible concentration of pollutants in water, air and food. The maximum permissible dose is the parameter used for the estimation of negative effects of physical fields (radiation, electromagnetic, ultrasonic) on the biota and humans. This environmental quality assessment model is derived from the safety concept based on safety thresholds for different aspects of anthropogenic action on the biota and humans.

After the Chernobyl NPP accident, radiation hygiene experts refused to use the safety threshold model in estimating the action of radiation on the humans and offered a radiation safety measure in the form of radiation disease probability per 1000 persons of those exposed to a collective dose. To estimate the genetic consequences of toxic substance exposure, we will also use this probability measure, as its application allows one to estimate the synergistic effects on the human body and the population stipulated by various cumulative anthropogenic effects.

In view of the above, the measure of ecological risk is accepted as the probability of death of a biological object (individual, population or species) within 1 year after an event where the maximum permissible dose has been exceeded (Anikiev *et al.* 1995; Fleishmann 1998).
The latter magnitude y_p is estimated on the basis of natural average life expectancy of biological objects "T" and safety degree k (for biota 0.1, and for humans 0.01):

$$y_p = k/T \qquad (1)$$

For the humans with an average life expectancy of 100 years, $y_p = 10^{-4}$, or E-4. The y_p calculation results summarized in Table 1 suggest that to maintain the human and biota populations, the ecological safety standards should be stricter by about 1-2 orders of magnitude than for individual biological objects.

Table 1. Permissible ecological risk for hydrobionts and humans.

Biological system	Life of biological system, years		Permissible ecological risk, $y_{p,t}$	
	Individual	Population	Individual	Population
Phytoplankton	0.0026	1.0	–	0.1
Zooplankton	0.3-0.5	1.0	0.3	0.1
Fishes	3-8	100-1000	0.3-0.001	10^{-3}
Humans	100	1000	10^{-4}	10^{-5}

To assess ecological risks in the coastal zone of the Sea of Japan we used two procedures based on:

1) estimation of critical biomass or numbers of hydrobiotic populations;
2) assessment of the cumulative action of pollutants on hydrobiota on the basis of known MPC.

If the variability of a hydrobiotic population obeys a normal distribution law, the ecological risk is estimated using the following formula, provided the effectiveness of estimates A, B and C is additive:

$$y \leq \begin{cases} 1 & \text{, at } E\nu < N_{crit} \text{ (A)} \\ (1 - E\nu / N_{\max})/(1 - N_{crit} / N_{\max})^2 & \text{, at } E\nu > N_{crit} \text{ (B)} \\ \exp[-(1 - N_{crit} / N_{\max})^2 / 2(1 - E\nu / N_{\max})] & \text{, at } E\nu > N_{crit} \text{ (C)} \end{cases} \quad (2),$$

where A is state at which the probability of population death is 100%, B and C are numbers of a population with a normal distribution and $E\nu$ = expectation of the number hydrobiots after exposure to an anthropogenic effect.

This approach was used for processing the experimental data on the spatial distribution of phyto-zooplankton and fish along the Vladivostok-Niigata cross-section in the Sea of Japan (Ambrosimov and Anikiev 1997).

Ecological risk was assessed from the pollutants concentrations data using the dose-effect functional connection (Anikiev 1997):

$$y = \alpha \varrho^s \quad (3)$$

where ϱ is the pollutants concentration, and s is the pollutants toxicity index ($\begin{cases} s > 1 \text{ - } safety \\ s < 1 \text{ - } poisons \end{cases}$).

By analogy to Equation 2, the ecological risk was calculated on the basis of the supposition about a normal distribution of pollutants in a marine environment:

$$y \leq \begin{cases} 1 & \text{, at z} > 1 \text{ (A)} \\ E\rho / LPS & \text{, at z} < 1 \text{ (B)} \\ \exp[-LPS / 2E\rho] & \text{, at z} < 1 \text{ (C)} \end{cases} \quad (4)$$

where $E\varrho$ is the expected concentration of pollutants distributed under the normal law:

$z = E\rho / LPS$.

Another formula for the assessment of ecological risk on individual species at cumulative influence of toxic substances is as follows (Fleischmann 1998):

$$y \leq \sum_{i=1}^{n} (E\rho_i / LPS) / n \qquad (5)$$

where n is the number of pollutants.

The ecological damage was estimated on the basis of the cost of seafood that becomes unusable as a result of its probable contamination. The general cumulative damage Y_s from the contamination of marine environment is defined as follows (Baburin 1998):

$$Y_s = Y(ND) + Y(NI) + ER + EC \qquad (6)$$

where Y (ND) is the damage to national resources as parts of the coastal zone population property created by their labor, Y (NI) is the damage to the national income, which is an industrial part of national resources alongside with manpower, and ER and EC are the restoration and compensation costs.

For the Amur Gulf in the coastal zone of Russia, the ecological damage to the national economy due to the decrease in fishing production for population was estimated (Baburin 1998; Ogorodnikova 1997):

$$Y_{ND} = E_0 \sum_{i=1}^{n} \frac{(c_i - MPC_i)}{MPC_i} V \qquad (7)$$

where Y_{ND} is the damage as a result of a steady-stated level of contamination, \$ / year, E_0 is the specific cost index of biological resources in calculation on 1 m^3 i.e., \$ m^{-3}, MPC_i is the maximum permissible concentration of polluting substances in waste fluids, ppm, and V is the volume of wastewater.

Obviously, the present partial approach yields only the bottom limit of probable damage without the account of secondary consequences.

Allocation of ecological risk on a transect across the Sea of Japan

Ecological risk was estimated from the data on chemical contamination of the sea obtained during two Russian-Japanese expeditions along the Vladivostok-Niigata transect in 1994-1995 (Figure 1).

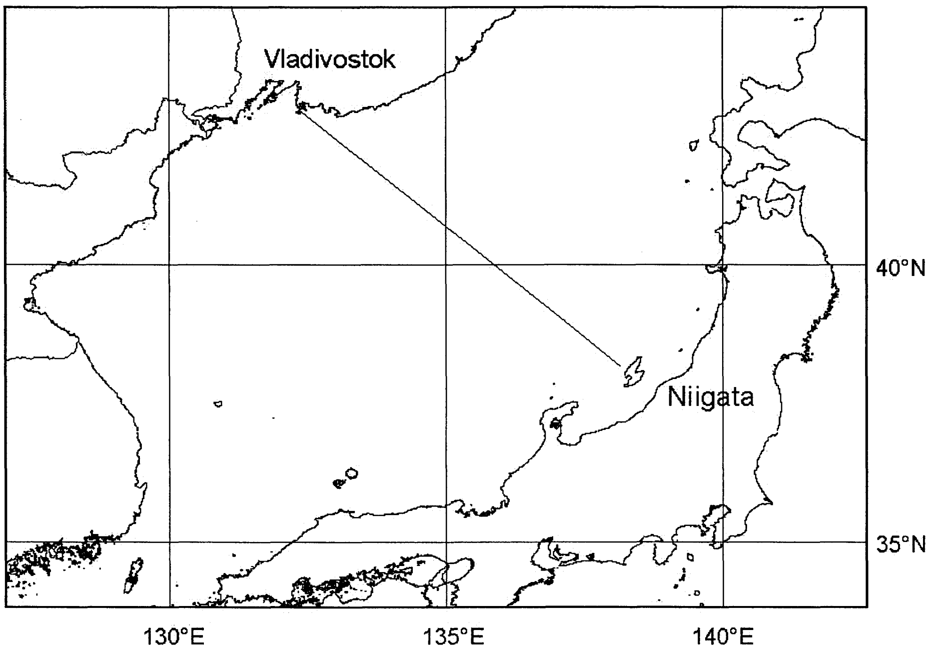

Figure 1. The sampling transect between Vladivostok and Niigata, Sea of Japan.

Two approaches based on the content of hydrocarbons (petroleum, polycyclic, aromatic and chlorinated) and heavy metals in seawater and bottom sediments, plankton and fish were applied to the assessment of ecological risk and the disturbance of the ecosystem structure.

As can be seen from Table 2, the ecological risk stipulated by the presence of hydrocarbons and dissolved heavy metals in the sea water exceeds the permissible level for fish populations by 1-2 orders of magnitude. The cumulative ecological risk is approximately 0.1, which is dangerous for some fish species.

Table 2. Ecological risk due to wastes in the Sea of Japan.

Waste product	Permissible concentration ($\mu g\ l^{-1}$) in Russia		Content of pollution matter ($\mu g\ l^{-1}$)		Ecological risk
	Tap water	Fishing resources	Observed in 1991–1995	Calculated	
I. Hydrocarbons of different classes					
a. Oil	300	50	0.36–1.0	–	0.002
b. Benz(a)pyrene	–	0.006	0.003	–	0.5
c. DDT and its metabolites	100	10	–	0.5	0.05
d. Σ					0.19
II. Dissolved fraction of heavy metals					
Fe	500	50	2.0	–	0.04
Mn	10	–	0.5	–	0.05
Zn	1000	50	0.25	0.1	0.05
Cu	5	5	0.25	0.1	0.05
Co	10	10	–	0.1	0.01
Ni	100	10	0.1	0.2	0.01
Pb	30	10	0.1	0.2	0.01
As	–	50	1.0	–	0.02
Hg	–	0.1	0.003	–	0.0003
Σ					0.03

To clarify the role of dissolved and particulate forms of heavy metals in the spatial distribution of ecological risk we divided the area into segments with their average concentrations (Tables 3 and 4) at three sites in the Sea of Japan.

Table 3. Average concentrations of dissolved heavy metals in different regions the Sea of Japan (10^{-9} g l^{-1}).

Element	Fe	Mn	Zn	Cu	Pb	Cd	Hg
Time and number of samples							
I. Coastal zone of Russia (h = 20-200 m)							
Peter the Great Gulf, 1989, n = 7	2700	600	200	100	240	90	-
II. Open area (h = 500-2000 m)							
Vladivostok–Niigata cross-section, 1995, n = 8	1900	132	1300	240	150*	15*	3,6*
III. Coastal zone of Japan (h = 20-200 m)							
Vladivostok–Niigata cross-section, 1995, n= 16	1900	170	2130	390	200*	15*	4,0*

*) observations of the Japan Environment Agency, 1991.

Table 4. Average concentration of particulate heavy metals (10^{-9} g l^{-1}), 1995, and their fractionation coefficients *) in concentration with sedimentation rocks of the Sea of Japan.

Element	Fe	Mn	Zn	Cu	Ni	Co	Cr	Si	Sc
Time and number of samples									
1. Coastal zone of Russia, 1994; n = 5	1000	360	132	60	190	3.3	3.1	3.2	1.5
	0.17	3.2	6.8	12.1	24.5	1.7	0.3	440	
2. Open ocean, 1994; n = 38	2330	133	204	108	92	3.6	18.8	5.4	0.45
	1.7	4.1	35.7	80	40	6.1	5.9	2400	
3. Coastal zone of Japan, 1995; n = 21	5785	210	561	192	175	4.5	23.3	9.1	0.5
	3.2	5.8	88.3	120	70	7.0	65.7	3600	

*) Results presented as fraction, where:

1. numerator is metal concentration;
2. denominator is coefficient of fractionation calculated using the function $K_{fr} = \frac{(x_i / Sc)_{sample}}{(x_i / Sc)_{sedimental\ rocks}}$.

These data (Anikiev *et al.* 2001) suggest that:

1) The concentrations of dissolved heavy metals in the Russian and Japanese segments differ substantially, possibly due to the differences in the river flow and drainage rock compositions.
2) For the particulate forms of heavy metals there is an inconvertible tendency of a 1.5–8-fold increase in their concentration and a 2–225-fold increase in the fractionation coefficient as one approaches the Japanese coast.

As can be seen from Table 5, the cumulative ecological risk due to dissolved and particulate heavy metals in the Sea of Japan is equal ~0.02

Table 5. Ecological risk due to dissolved and particulate heavy metals (10^{-9} g l^{-1}) in the Sea of Japan *).

Element and area	Fe	Mn	Zn	Cu	Ni	Co	Cr	Pb	Cd	Hg	Risk ratio
1. Coastal zone of Russia	.0054	.006	.002	.002	–	–	–	.0024	.0018	–	.0028
	.0020	.0036	.0013	.0012	.0019	.0033	.0006	–	–	–	.0012
2. Open ocean	.007	.0013	.0013	.0048	–	–	–	.0048	.0015	.0035	.0044
	.0046	.0013	.002	.0022	.0009	.0036	.0037	–	–	–	.0031
3. Coastal zone of Japan	.0070	.0017	.0021	.0078	–	–	–	.002	.003	.004	.0061
	.0011	.0021	.0056	.0038	.0018	.0045	.0046	-	-	-	.0031

*) Results presented as fraction, where:

1. numerator is ecological risk significance for dissolved heavy metals;
2. denominator is the same as for particulate heavy metals.

This increase is natural, as the establishment of the industrial infrastructure in the coastal zone of Japan was completed at least 20 years earlier than in Russia.

To assess the ecological risk associated with ecosystem structure disturbance we used ultrasonic data on aqueous masses recorded during the movement of the vessel and data on phytoplankton registered with a laser fluorimeter along four sequential sections between Vladivostok and Niigata (Figure 1). To estimate the variability scales of plankton spatial distribution and the shoals of fishes along the section we calculated their distribution histograms, which obeyed the exponential law with the parameters:
$\lambda_{plankton}=4.4$ km^{-1} and $\lambda_{fishes}=4.15$ km^{-1}.

This result suggests that the abundances of individual species in both populations obey a normal distribution law.

On the basis of these calculations and the 19 resultant distribution histograms, we established that the magnitude of ecological risk reaches a value 0.2 on the shelf of Russia and increases to ~0.28 as one approaches Japan (Figure 2). The stable magnitude of ecological risk is 2-3 times higher than the risk level due to chemical contamination of the ocean water.

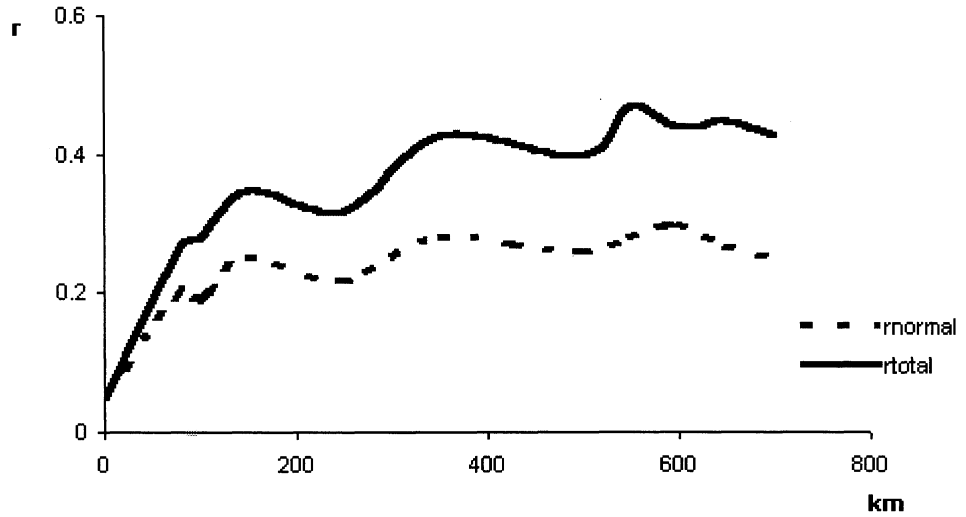

Figure 2. Spatial variability of the ecological risk significance at total (r_{total}) and (r_{normal}) laws of distribution on the transect across the Japan Sea between Vladivostok and Niigata.

The agreement of the above ecological risk estimates obtained using different methods suggests that the present assessment of anthropogenic influence on the plankton-fish ecosystem is fairly complete. However, the Sea of Japan may contain additional toxic matters, for example supertoxicants, including poisoning substances and their decomposition products. The inflow of poisonous substances into the photic layer may occur from the sites of chemical weapons sinking that USSR and Japan carried out for several decades (Fedorov 1994).

In view of the high potential danger of poisonous substances present in the seabed we carried out special examinations to identify bottom sediments.

Proof of the presence of poisonous substances in the bottom sediments of the Sea of Japan

Identification of poisonous substances in bottom sediment samples taken along the Vladivostok-Niigata cross-section (Figure 1) was carried out for the indication of the following parameters (*cf.* Anikiev *et al.* 2000):

1. Characteristic relationship between the basic elements of organic components i.e., O, C, N, P and S.
2. As/Sc fractionation coefficient used in geochemistry for estimating the effect of various factors on the chemical composition of natural objects;

3. Anomalies in the distribution of heavy metals that may be caused by the inflow of chemical munition shell corrosion products.

An unusual relationship of organic component compositions in the bottom sediments was revealed in samples taken in 1994 on the shelf of Russia.

The contents of principal organic components in the sectional sample decreases in the following order: O (31.8 %) > C (20.3 %) > Cl (10,3 %) > S (3 %) > N (3 %) > P (0.8 %). This order differs essentially from the stoichiometric model of natural organic ocean water composition as described by the Redfield ratio (C:N:P = 106:16:1) and other natural objects (average composition of Earth biomass, soil humus and the organic matter in bottom sediments).

Evidence for possible presence of poisoning substances and/or decomposition products is the proximity of Cl/C and S/C relations in the test sample of bottom sediments to the stoichiometric formula of yperite and lewisite (Table 6). As can be seen, the experimental Cl/C and S/C values differ from the appropriate relationships in the stoichiometric formula of yperite by 3-4 times, whereas their difference in comparison with the average composition of Earth biomass reaches two orders of magnitude or more.

Table 6. Cl/C and S/C fractions in the bottom sediments, poisonous substances and natural organic substances.

Ratio	Bottom sediments	Poisonous substances		Living matter on the Earth
		yperite	lewisite	
Cl/C	0.51	1.48	1.45	1.1×10^{-3}
S/C	0.15	0.66	–	2.0×10^{-3}

Thus, yperite can be present in the bottom sediments, and its decomposition products preserve a considerable portion of the parent chemical structure.

Additional evidence for the presence of poisonous substances in the bottom sediments is the 2–10-fold higher content of Fe, Zn, Ni, Co and Pb in comparison with the adjacent sites (Table 7).

Table 7. Metals concentration in the surface layer of bottom sediments in the Sea of Japan (µg/kg), 1994.

Station	Fe	Sc	As	Zn	Co	Ni	Pb	Cd
1	9000	5.3	3.7	15.0	1.5	4.4	5.0	1.3
2	28500	6.1	8.2	57.0	18.0	32.0	25.0	1.3
3	17500	7.3	5.6	37.0	7.5	14.0	16.0	1.5
5	9500	3.7	6.0	25.0	5.0	9.5	5.0	0.8

To identify the second most abundant poisoning substance i.e., lewisite, we used the same distribution as for the bottom sediments.

As can be seen from Figure 3a, the As/Sc fractionation coefficient in the surface layer of the bottom sediments of the Sea of Japan varies in the range from 1.0-6.0, whereas in sedimentary rocks it is 0.66. Some sites at which K_{fr} varies in the range from 2.0-5.9 are the sites at which lewisite sinking could be made. Arsenic is known to constitute 30% of this poisonous substance by weight.

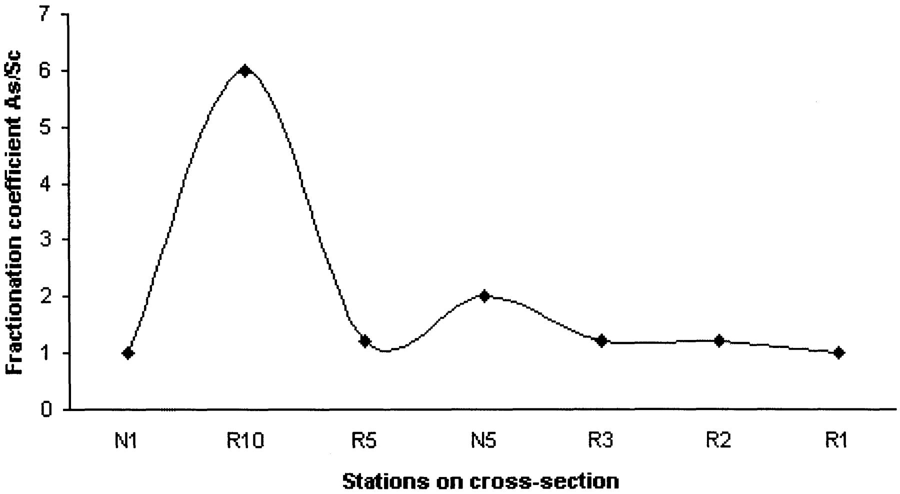

Figure 3a. Distribution of the As/Sc fractionation coefficient in the surface layer of the bottom sediments on the transect across the Russia shelf.

In comparison with the upper layer (0-5 cm) of the bottom sediments, K_{fr} increases with depth (20-30 cm) by 2-6 times (Figure 3b), and this is possibly related to flooding of the ground mass of chemical ammunition.

After checking of the examination results the question may arise concerning the moratorium on the use of seafood from the Sea of Japan, and quantification of possible damage may be required.

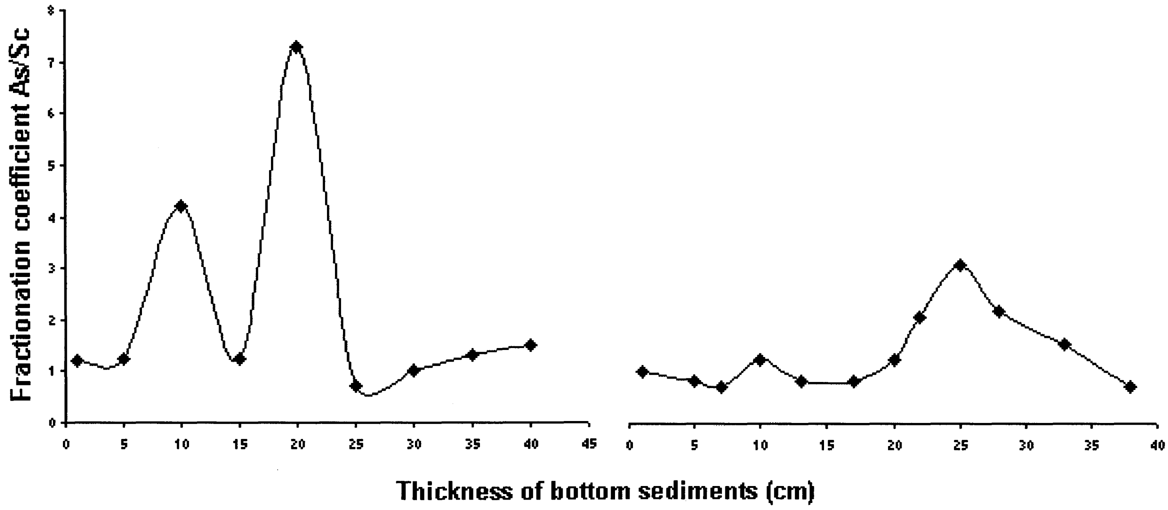

Figure 3b. Variability of the As/Sc fractionation coefficient in thickness of the bottom sediments on the Japan shelf.

Ecological damage assessment

For the quantification of ecological damage due to the presence of supertoxicants we use the conventional method i.e., directly calculate the losses caused by the introduction of the moratorium on the use of seafood during a particular period of time.

The calculations have shown that the total ecological damage for the Sea of Japan can be as high as $1.46 billion/year under the following conditions (Anikiev *et al.* 2001):

1) the specific cost estimate of biological resources per m^3 of the explored water layer is \$0.00730 /year;
2) the volume of ocean water required for the dilution of arsenic compounds (which can be supplied from lewisite flooding sites) to the maximum permissible concentration is 200 km^3, or $2x10^{11}$ m^3;
3) the damage or loss of biological resources for Southern Korea and Japan will be 0.48 and 1.5 of the appropriate damage level for Russia, respectively, according to the ratio of total seafood extraction volumes from the Japanese sea by these countries in 1992.

Another method of calculating ecological damage, based on direct losses from the incomplete use of seafood, has shown an ecological damage of \$1.52 billion/year. The agreement of damage calculated for various input data suggests reliability of the calculations.

Based on the water exchange rate between the Sea of Japan with the Pacific, one should expect that the moratorium is required for at least 10 years. Thus, the aggregate ecological damage can be about \$14.5 billion.

In the future we intend to reconsider the present sectional estimate with a greater magnification, because in the present calculation only part of the total biological resource was taken into account and the minimum values of input data were used in the calculations.

We will compare the results of our estimates with the calculation of ecological damage in the Amur Gulf due to wastewater drainage (Ogorodnikova *et al.* 1997).

The total annual ecological damage due to the inflow of wastewater into the Amur Gulf (20 km^3) is \$0.414 billion/year. Thus, the ecological damage per km^3 of coastal zone water from the present calculation is 3.5 times higher than the total for the Sea of Japan.

Table 8 suggests that the basic negative factor in the quality of the Russian coastal zone water is the wastewater of municipal facilities. The effect of the pollutants on the ecosystem obeys the following order: organic compounds > biological components > phenols > synthetic surfactants > heavy metals (Ogorodnikova *et al.* 1997). However, the latter factor of the above, i.e. the heavy metal pollution, is the major ecological risk factor for the Vladivostok-Niigata cross section. This suggests assimilation of all organic compounds and nutrients in the Amur Gulf, which is a shallow component of the coastal zone in question. Obviously, a considerable portion of heavy metals is transferred through the shallow zone to the deep-water part of the Peter the Great Gulf and farther to the open regions of the Sea of Japan.

Table 8. Relative contributions from branches of industry to the ecological damage in the Amur Gulf (Ogorodnikova *et al.* 1997).

Branch	Municipal facilities	Industry	Agriculture	Others
Contribution to the damage, %	71.5	24.0	2.5	2.0

Conclusions

1. Analysis of the ecological risk distribution has shown that there is a substantial danger of loss of the plankton-fish ecosystem due to chemical contamination of the Sea of Japan.
2. In the shallow coastal zone of Russia (the Amur Gulf), the detrimental effect on environmental quality is basically determined by the organic components of municipal wastewater, whereas for the remainder of the Sea of Japan heavy metals play a major role in the contamination.
3. Indirect evidence for the presence of poisonous substances (yperite and lewisite) in the shelf bottom sediments of the Sea of Japan has been found, and this should impel local authorities to adopt a moratorium on the consumption of seafood by the population of the adjacent areas in the future.

4. The present information can be used for the UNEP-NOWPAP regional project aimed at the environmental protection of the Sea of Japan and the Yellow Sea.

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5.12 Environmental conditions in the Rudnaya River watershed in the Russian Far East

Anatoly N. Kachur

Introduction

The North West Pacific is receiving increased anthropogenic load on the natural environment, caused by the extension of resource developments and new impacts on natural components and ecosystems.

One of the major ecological problems in the Far East of Russia is the basin of the Rudnaya River. The Rudnaya River Valley is a rich reserve of lead ore and has been mined for nearly 100 years. The Rudnaya River basin lies within the Eastern Sikhote-Alin, a mountain range with isolated high mountains, small ranges with sharp peaks and rocky cliffs that reach 1,000-1,200 m. The main mountain ranges lie in a north-eastern direction.

The hydrographic net of the region is presented by the Rudnaya River 73 km long and with a watershed of 1140 km^2 at an average altitude of 395 m. The river is a typical mountain stream flowing swiftly down steep slopes.

Significant oceanic influence is felt in the coastal part of valleys where climate is milder. Alteration of seasonal air streams leads to sharp changes of the wind speed and direction. Vegetation cover of the Rudnaya River basin is in the transitional zone between coniferous-deciduous forests and deciduous (generally oaks).

Soil cover of the basin is not distinguished by great variety of types. The zonal basin soils are brown forest soils, as throughout South Primorye. The soils that develop in the Rudnaya River valley create oxidizing-reducing and alkaline-acid conditions under which unlimited discharge of mobile compounds occurs including calcium carbonate, while these conditions not favourable for transfer of R_2O_3 type oxides, oxides and hydroxides of metals, or organic-mineral compounds.

When the southern part of the Far East was included in the Russian State during the middle of the 19th century, only hunters and fishermen from the tribes of Udage, Tazy and Goldy lived in what is now the Dalnegorsky region. Excavations show presence of large settlements at different times in the region. Traces of furnaces have been found from the early middle ages, for lead and silver ore processing in the upper Rudnaya River. That means that metallurgical crafts have been carried out in the region since ancient times.

Modern industrial production began in 1897, when an expedition under mining engineer S.V. Maslennikov occupied the area, known to miners, of lead-zinc-silver deposits where the "Dalpolymetal" joint-stock mining company was based. At present "Dalpolymetal" includes five mines, three ore-concentrating factories and a plant that produces refined lead, bismuth and silver.

Aero-space information analysis shows that the entire valley of the Rudnaya River is under constant contamination stress and its geosystems have already changed structures at different rates. General sources of contamination are in Krasnorechensk settlement, Dalnegorsk town and Rudnaya Pristan settlement. Analysis of results for many years of observation demonstrated that the general contamination's source is gas-dust discharge from the main industrial points of the region. The present situation in the Rudnaya River valley can be characterized as pre-crisis.

The reasons for the situation are the following:

- an intensive growth of industry, especially of the "ecologically" most dangerous branches - poly-metal and chemical, which has entailed an increased in pollutants with gas-dust emissions, economic and sanitary wastewaters. In some cases unique technologies are being developed, with no analogs in the world production and, consequently, no analogs of treatment;

- a growth of atmospheric pollution with toxic substances released by motor transport - the main transport means in the region;
- development of this ore unit without proper consideration for its physico-geographical specifics. At present the main processing enterprises are found in cup-like parts of the valley where inversions are common. Settlements are so located that in the summer they are subject to prevailing impact of pollution. Chimney heights in enterprises are such that pollution of terrestrial air affects most the settlements, and prevailing wind speeds correspond to the most dangerous speeds of pollutant transfer.

A heat-water relationship in a warm season facilitates conversion of pollutants into the most aggressive forms.

Settlements are usually located downstream from ore mines, processing factories and others, so the population cannot use water from nearby streams.

As a result of the combination of the above reasons, active degradation and decay of terrestrial and water ecosystems are occurring in some parts of the Rudnaya River basin, including Rudnaya Bay. The principal source of pollution is gas-dust emissions from the main industrial enterprises in the region. Table 1 gives average annual values of pollutants for some settlements.

Table 1. Average annual values of pollutants in main settlements in the Rudnaya River valley (mg cu^{-1} m^{-1}).

City	SO_2	NO_2	CO	Solid matter
Dalnegorsk	0.02	0.04	0.99	0.25
Rudnaya Pristan	0.01	0.03	0.83	0.32

Analysis of average annual concentrations of heavy metals in terrestrial air of the Far East Settlements has indicated that of all the metals analyzed, the MAC figures are exceeded only for lead in Rudnaya Pristan and Dalnegorsk (an average daily MAC is 0.3 mkg cu^{-1} m^{-1}). In Rudnaya Pristan the average annual concentration of lead is twice as high as MAC. These are the highest lead levels in the atmosphere of all the monitored cities in the Russian Far East. There are clear-cut zones of pollution several hundreds of square kilometers around these sources. Rudnaya Pristan and Dalnegorsk comprise a separate polluted zone.

The lead-smelting plant of "Dalpolymetal" is situated at the Rudnaya River mouth and 1.5 km from the bay, covering an area of about 2.5 ha. It has been operating for more than 60 years. The plant is engaged in processing concentrated sulphide lead ores by smelting in furnaces. Production wastes (slag) are stored as heaps. The slag contents are predominantly zinc (15%), iron (20%), lead (2%) and other metals. All these elements are present as metals oxides, sulphate, sulphides, silicates and ferrites. The leadplant is the source of much of the industrial and domestic waste waters (up to 2900 m^3 every day). Industrial and domestic discharge into the pond annually brings more than 100 kg of lead, 50 kg of zinc and copper, 20 kg of arsenic. The discharged effluxes have alkaline reaction (pH to 8.5) considerable turbidity (contents of suspended particles 0.4 g l^{-1}). At the exit from the plant pond this water differs strongly in contents from natural water (Tables 2 and 3).

Concentration of most elements is higher, namely bicarbonates 1.4 times more, chlorine 1.5 times more, sulphates and potassium 3 times more. Arsenic concentration reaches almost 1 mg l^{-1}, in some samples 2-3 mg l^{-1}, which is 12-40 times higher than the permissible level for drinking water and 3.5-4 times more than the permissible level for waste waters in Russia. The arsenic concentration of these waters makes them highly toxic for fishes (lethal dose of arsenic for salmons is 1-2 mg l^{-1}).

Appraisal of surface and ground waters has indicated that throughout the Rudnaya River valley, surface and ground waters are heavily polluted, in many places their composition endangers human health at normal contacts with water.

Table 2. Chemical composition of waters of mining objects (mg l^{-1}) in the Rudnaya River basin (from Elpatievskiy).

Component	Type of water						
	1	2	3	4	5	6	7
pH	7.54	7.83	6.66	2.36	6.52	7.72	6.92
SO_4	10	382	570	15270	377	55.6	552
As	n. det.	<0.002	0.005	3.1	0.005	n. det.	0.005
Ca	7.0	70.7	137	455	122	34.8	167
Mg	0.12	32.0	56.0	903	67.7	8.7	35.9
Na	3.3	22.3	25.0	9.7	11.0	3.7	15.0
K	0.51	2.2	3.2	4.4	6.0	2.4	16.0
Fe	0.0026	0.021	0.09	3046	0.048	0.008	0.003
Al	0.03	0.023	3.8	1228	3.8	2.2	3.8
Zn	0.008	1.97	8.0	658	0.143	0.133	0.082
Mn	0.0016	0.89	8.6	1850	6.7	0.56	0.094
Cu	0.0004	0.0048	0.0008	2.2	0.012	0.001	n. det.
Pb	n. det.	0.0026	n. det.	0.44	n. det.	n. det.	n. det.
Cd	0.00006	0.01	0.022	2.54	0.003	0.0008	0.00006

Type of Waters:
1 – clean waters of the Rudnaya River heads.
2 – the stream, draining the mine tested in 1989.
3 – the same stream tested in 1997.
4 – waters of the upper pool of the "old" mine tailing.
5 – drainage waters of the "old" tailing.
6 – waters of the upper pool of the "new" tailing.
7 – drainage waters of the "new" mine tailing.

An enterprise of nonferrous metallurgy is the major contributor to the atmospheric pollution in this settlement. Analysis of fallout has shown that more than 50% is metal sulfides with a dominating lead content. Mobile forms of compounds make up 33-45% of the total amount of metals on soil surface and in organic residues.

Table 3. Contents of metals in dispersion matter (weight %, per dry matter) (from Elpatievskiy).

Sampling place, characteristics of matter	**Elements**					
	Fe	Zn	Mn	Cu	Pb	Cd
1. Suspended matter of the stream, draining the mine, sampling of 1989.	5.06	10.37	0.66	0.022	0.29	0.011
2. As for 1, sampling of 1997.	34.25	3.89	0.096	0.028	0.077	0.0088
3. Suspended matter of "vitrioloc" waters of the upper pool of the old mine tailings.	31.0	0.28	0.84	0.0033	0.0055	0.00022
4. Suspended matter in drainage waters of the old mine tailings.	39.5	0.79	0.27	0.0097	0.11	0.0023
5. Sediment of Fe hydroxides, as for 4.	56.6	0.31	0.24	0.0062	0.076	0.0017
6. Sulfide sediment, as for 4.	44.2	2.22	1.16	0.058	0.63	0.01
7. Suspended matters of the upper pool of the new mine tailings.	34.2	3.89	0.096	0.027	0.077	0.0087

In the river runoff, technogenic compounds exceed 70% of the whole ion runoff (SO_4 = 90%, F = 85%, B = almost 100%). In the Rudnaya River mouth, as a result of dilution with inflowing water, technogenic macroelements content about 40-50%, microelements: Zn 90%, As and Pb 80%, Cu and Sn 75%. Pollution of surface waters makes them unsuitable for use, and the Rudnaya River fishery is unusable.

The gas-dust discharge volume from the lead-processing plant into the atmosphere is considerably higher than the discharge with waste water: for heavy metals it is 300-500 times more, for arsenic 250, sulphur 100 times more. The gas-dust discharge in summer goes north-west direction (up to the Rudnaya River valley) or north (up along the Koreyskaya Pad), while in winter it goes south-east towards Rudnaya Bay.

Together with gas-dust discharge, more than 85 tonnes of lead dust, which includes some 50 t of pure lead, 5 t of zinc, 6 t of antimony, 1 t of bismuth and 0,5 t arsenic, penetrate into the atmosphere annually. As well, about 4,800 tonnes of sulphur dioxide and more than 200,000 tonnes of carbon oxide and carbon dioxide add to its mixture.

Since 1964 only mechanical dust cleansing of gaseous discharges is done at the plant. Efficiency of cleansing is about 95% (according to data of the plant laboratory and local Sanitary Station). Before 1964 the cleansing of gas-dust discharges was not been done at all.

In both winter and summer near the plant, the concentration of calcium ions has increased 3 times and that of sulphate ions 1.5 times. Mineralization of snow is 50% higher than rain. Snow in the plant vicinity contains great quantities of insoluble dust, the composition of which points to its technogenic origin, namely zinc and lead concentrations are about 3-5%, arsenic and copper up to 2%, bismuth and antimony up to 0.5%.

Significantly more contrast is observed in the composition of microelements in mobile forms. In the zone of air maximum contamination, precipitation content of lead is 200-1000 times more than normal and in several winter samples it is 5,000 times more. Precipitation contains zinc 100 times more, copper and arsenic 50 times more, silver 20 times more. Lead concentration exceeds not only permissible level for drinking water and reservoirs (0.1 kg l^{-1}), but in several samples is higher than permissible level for waste waters (1 mg l^{-1}). The total amount of soluble matter of precipitation in the zone of the plant influence reaches 500 tonnes while the technogenic component is 100 t of the total.

Simultaneously dropping with precipitation more than 200 kg of arsenic (natural constituent less than 10 kg). Lead (natural constituent about 3 kg) is 3 tonnes in the zone of the plant influence.

The levels of metals in excess of the regional-background levels, i.e., the anomaly degree, are as follows:

Pb (61.2 times) > *Cd* (37.0) > *Zn* (15.4) > *Cu* (11.7) > *Mn* (2.2) > *Fe* (2.0).

Only a small part of technogenic discharges is being washed away from atmosphere in dissolved form, namely 6% of lead, 4% of zinc, less than 1% of bismuth.
Around the settlment Rudnaya Pristan is an extended zone of pollution. The vegetable cover and surfaces of leaves are initial acceptors of the atmospheric depositions. An examination of the chemical composition of waters showed that, after contact with surfaces of leaves, total mineralization of solutions increases nearly twice. In soluble material washed away from the crowns of trees by rains, the sulphate compounds of lead predominate.

Air contamination by sulphur gases and carbon oxide dust near the plant is many times more than permissible levels and has caused significant damage to vegetation cover. At a distance of 1.5 km from the plant over an area of 30 ha, vegetation has died and has not regrown. Here, the soil cover is subjected to intensive denudation and erosion. Beyond this zone over an area of some 40 ha, the soil surface is covered by meadow. At a distance of 2-3 km from the plant, some oak woods reach 5-8 m high with the canopy of leaves of 0.5-0,6. Under the trees the usual brown forest soils are developing, although they lack an underlying horizon.

In the zone of maximum pollution all plants have evident features of distress. The general reason is, probably forcing of sulphur gas and carbon monoxide fumes.
Probable reasons of the vegetation distress may be higher concentrations of chlorine and arsenic in the air. In the oak leaves, the sulphur concentration is higher near the plant (up to 0.15% compared with 0.09% normal), oblique evidence of the dominating role of sulphur gas in the vegetation distress.

Spectral analysis of ash showed that ash of the oak leaves which were washed clean of dust was enriched by heavy metals, namely lead and zinc up to 0.11%, arsenic to 0.1%, copper and tin. All these concentrations are two or more times higher than normal.

Analysis of foodstuffs grown in these zones showed them unfit for consumption. Agricultural areas including vegetable and fruit gardens need to be moved away from the polluted zones.

The Dalnegorsky region is one the most unfavorable regions regarding its ecological-hygienic problems. In the beginning of 1980's Medical State University researchers found sharp anomalies of structure and level of morbidity in Dalnegorsk, but this information has not been used to develop measures for environmental and population health-improvement.

In Rudnaya Pristan the average annual level of lead is twice as high as MAC. These are the highest concentrations of lead in the atmosphere among monitored cities in the south of the Far East. Acute inhalational pathological reactions in both children and adults have no use as indicators of air contamination, because exceeding of infection morbidity levels of respiratory organs is very small (1.1-1.3 times) probably due to long-acting atmospheric air contaminants of the biosphere and other components to the human organism which have cumulative effects leading to damage of the main system of organism and disorder of its reactivity. These are confirmed by morphological changes of blood cells element in the population of Rudnaya Pristan.

The research carried out in Rudnaya Pristan showed that unfavorable factors of metallurgical production lead to functional (previously pathological) alterations and pathological status beginning in the employees.

The morbidity level in Dalnegorsk during 1987-1989 was 1.2 times higher than the average in Primorye. Respiratory diseases take first place in the morbidity structure, with the highest level among the industrial centers of Primorye (during 1987-1989, an average 538 cases per 1000 head of population).

In Rudnaya Pristan the unfavorable ecological situation leads to accumulation of toxic elements in organisms, including heavy metals at near critical concentration rates. Sampled hair from children in kindergarten showed lead concentrations up to 9.6 $\mu g\ g^{-1}$ when background is equal to 0.44 $\mu g\ g^{-1}$, and the average lead level children's hair is 5.6 $\mu g\ g^{-1}$. The average lead concentration in employees' hair from the lead processing plant was 286.6 $\mu g\ g^{-1}$ (in a control group of population from Terney it was 6.7 $\mu g\ g^{-1}$) and the average concentration of cadmium was 6.7 $\mu g\ g^{-1}$ and 0.6 $\mu g\ g^{-1}$ respectively.

The level of malignant neoplasms is twice as high in Rudnaya Pristan than is supposed to be ecologically safe, namely of the tumor of the lungs and stomach is 4.9 times higher, lymphatic and blood-forming tissue 33 times more. Infection morbidity in the settlement isn't higher than average for Primorye.

In the Rudnaya Pristan, an acute rise of chromosome damage is found in mouse-like rodents under forcing of unfavorable ecological conditions.

The population health status demands urgent measures to be undertaken for its rehabilitation, especially concerning children. In 1989 researchers from the Pacific Institute of Geography offered a program on medical-preventive work in the Rudnaya Pristan region. Moreover, researchers from the Pacific Institute of Bioorganic Chemistry of FEB RAS in this program offered some medicines that have been tested on a small group of workers from the lead processing plant, but this program has not yet been applied widely.

Note: no references provided.

5.13 The state of the freshwater environment and the associated marine and coastal environment in the Sea of Japan basin

Anatoly N. Kachur

The Sea of Japan is a marginal sea of the Pacific Ocean, surrounded by Russia, Japan and Korea. Via the Korea Strait in the south it is connected with the East China and Yellow seas, via the Tsugaru Strait (Sangarsky) with the Pacific and via the Strait of Tatarskyi and the Laperuz Strait with the Sea of Okhotsk .

The Russian section of the Sea of Japan basin comprises medium and small rivers running from the eastern slope of the Sikhote-Alin and Eastern Manchurian mountain ranges. River basins have steep slopes; liquid and solid flow is significant. Basins of rivers flowing into the Sea of Japan are as large as 1,900 km^2. Apart from this, a small portion of the Amursky River flow gets into the Sea of Japan via the Tatarskyi Strait.

The Russian section of the basin supports 1.6 million people, including 1.2 million in Primorsky Krai, 140,000 in the Khabarovsk oblast and 217,000 in the Sakhalin oblast. Altogether more than 50 million people live on the mainland and islands of the Sea of Japan basin, permanently or temporarily. However, taking into consideration waters brought with the Tsushima current, about 60 million people more live permanently beyond the basin boundaries. The Amur River also partly contributes to the composition of coastal waters of the Sea of Japan.

In the basin, the main environmental changes have occurred during the last century. The mainland has suffered most. The primary forests that were growing here until 100 or 150 years ago have practically lost their original appearance.

Soil cover is one of the most important resources for mankind. In this very large territory subject to intensive technogenic impact, ore mining activity will spread over practically the whole territory.

By virtue of the geological, historical and political factors in this region, the economic management system that developed here has led to a sharply polarized development of the territory, not only by intensity, but also by specialization. The economy of the Far-Eastern regions developed without proper consideration of ecological consequences, or a nature-conservation policy. Development in the region has upset the ecological balance in many regions. Primary ecosystems throughout much of the Russian section of the Sea of Japan basin have changed enormously.

Metal pollution is also very prevalent. In cities and settlements in the south of the Russian Far East, maximum permitted concentrations of lead were exceeded in several places (an average daily admissable concentration is 0.3 kg m^3) and in Rudnaya Pristan the annual average level of lead is twice as high as normal, due to pollution from the several large cities in the Japan Sea basin. For example, in Vladivostok, which is the largest city and industrial centre on the Russian coast, pollutants from stationary sources were equal to 79.9×10^3 t yr^{-1}, including solid matter (42.8), sulphur anhydride (27.4); nitrogen oxides (3.6); carbon oxides (4.6); hydrocarbons (1.3) and others (0.09) in the late 1980s and early 1990s. Emissions including vehicle transport were 124.3×10^3 t yr^{-1}.

The main contributors to emissions are industries related to fuel energy 68.3%, construction organizations 8.4%, the marine fleet 12.1%, and the ship-repair industry 4.8%. In the last five or six years the load on air pollution in the south of the Russian Far East has somewhat diminished, but this is not connected with an improved treatment of emissions, but with a decline in production. When the economy recovers, air pollution will increase. The concentrations of some elements (Pb, Cu, Zn, Mn) which are monitored in the atmosphere are insufficient for an objective appraisal of the environment. Seasonal dynamics also affect the concentrations. For example, in Vladivostok, Nakhodka and to some extent in Sovetskaya Gavan and Vanino, concentrations of pollutants are highest in spring and autumn; in Artem, pollutant concentrations are lower in summer; in Dalnegorsk and Rudnaya Pristan concentrations of solid matter and some other pollutants are constantly high and exceed maximum admissible levels. These situations are dependent to some extent on emission sources in a particular city, but in all cities the concentrations of many pollutants are higher than is admissible, which is indicative of a dangerous level of pollution. In general, sulphur load is 0.25 to 1.0 t km^2 and nitrogen from 0.5 -2.0 t km^2.

A composition and degree of pollution of surface and ground waters are of great importance not only for localities where these waters flow, but also for the whole basin. Water pollution is made up of atmospheric fallouts, discharges and effluents from enterprises and settlements, and sheet wash of pollutants from land. All three factors are acting intensively in the Sea of Japan basin.

In fact, all rivers in the Sea of Japan basin are subject to pollution to various degrees (Table 1). This is also true of the Amur River basin that partially contributes to pollution of the northern part of the Sea of Japan.

Table 1. Comparative content of elements in dissolved (μk g l^{-1}-A) and suspended phases (%-B, 10^{-3}-B1) of river waters.

Region	Fe		Mn		Zn		Cu		Ni	Cr	Pb	Cd
	A	B	A	B	A	B1	A	B1	B1	B1	B1	B1
Eastern Sikhote-Alin	22.9	3.1	3.5	103.2	52.7	142.0	1.2	14.7	16.4	4.1	31.9	0.94
Watershed of Peter the Great Gulf	57.8	4.0	11.6	130.7	41.9	107.2	1.5	12.2	8.2	7.2	20.5	0.35
Average for world rivers (Gordeyev 1983)	410	5.1	10	100	20	31	7.0	8.3	8.4	13	14.7	0.07

The rate of runoff of dissolved and suspended matter from the Amur basin is about 20 t km^{-2} yr^{-1} each.

Most surface waters are polluted, but their mineral and ionic composition largely comply with the requirements of drinking water supply, except for several rivers in the north and east of the Gulf of Peter the Great, and rivers in the main ore-mining regions in the Central Primorskyi Krai. Here rates of runoff are much higher, 30-50 t km^{-2} yr^{-1}. According to estimates, specific annual releases of polluted waste waters per urban citizen in the Primorskyi Krai in 1989-1990 averaged 183 m^3 man, that is nearly 30% more than the Far East average.

In agricultural regions water pollution is caused by seepage from fields that are treated with chemicals and fertilizers (primarily from irrigated fields) and waste waters from animal farms (middle reaches of the Razdolnaya River, the Tumangan River basin). Water pollution is so high because of a low efficiency of wastewater treatment (an average figure for the Primorskyi Krai is not more than 15%).

Analysis of pollution of surface waters with one of the main pollutants - heavy metals (HM) has indicated that the situation in most river basins does not stir anxiety. The northern regions of the Primorskyi Krai and regions of the Khabarovsk Territory, part of the Sea of Japan basin, and some highlands, watersheds of rivers and sparsely populated areas in the south of the Primorskyi Krai are not subject to perceptible HM pollution. A great part of the southern half of the Primorskyi Krai can be classified as an area with a moderate HM pollution of waters. This is revealed in a higher level of one or several parameters, or in pollution of waters in ore-mining areas.

Pollution of rivers with HM and other chemical components is associated with sanitary and industrial wastewaters from the cities Vladivostok, Partizansk, Nakhodka, Dalnegorsk, Vanino and Sovetskaya Gavan, and also with areas of intensive ore-mining.

Pollution of surface waters becomes still heavier in industrial zones. In regions with the developed ore-mining, pollution from heavy metals, sulfur compounds and others becomes more intensive (e.g., basins of Zerkalnaya, Rudnaya rivers); in regions with developing production and processing of agricultural produce there is pollution from organic substances, nitrogen and others (basins of the Razdolnaya, Tumen and other rivers).

The problem becomes more serious in the face of planned development of a free zone for the Tumen River. Already this region is polluted, whereas only 15-20 years ago pollution in this basin was insignificant. According to available information, nearly all enterprises in China and Korea Democratic Republic do not have treatment facilities. Endangered are not only the Marine Nature Reserve in the Peter the Great Gulf, but also coastal sea areas.

Groundwater in the Russian section of the Japan Sea basin, and especially in the Primorskyi Krai, can be described as satisfactory, although there is a potential for significant pollution especially of some aquifers. Groundwater aquifers need restriction of economic activities within their catchments and within watersheds of rivers crossing these territories.

Analysis of coastal-marine waters have indicated that the western coast of the Sea of Japan can be divided into four regions:

1. Amur Lagoon
2. Northern
3. Central,
4. Southern regions of the Primorsky Krai.

The coastal-marine waters of the Korean Peninsula complement these four regions.

Water composition in the Amur Lagoon is controlled to a great extent by a part of the Amur River flow, as well as coastal settlements on Sakhalin Island. In the lagoon waters there is a high content of detergents, petroleum hydrocarbons and heavy metals, and a rather high turbidity. The effect of the Amur River flow can be followed (by heavy metals content) as far as the coastal waters of the Sikhote-Alin Nature Reserve. In recent years the state of marine ecosystems has aroused serious anxiety in connection with development of oil production in the territory of Northern Sakhalin and the coastal shelf.

The Northern region spreads from Zolotoy Cape to Povorotny Cape. In this region there are several local sources of significant pollution of coastal waters, largely waste waters from ore-mining and ore-chemical productions. The largest of them is located near Rudnaya and Zerkalnaya bays. Pollution is characterized by the presence in great quantities of Pb, Cu, Zn, Cd, As, B and others in dissolved and suspended forms. In the polluted zones, build-ups of pollutants are revealed in bodies of marine hydrobionts, which make them inedible. No deviations from background levels are found in the area of Olga Bay, the harbor base of the Pacific Fleet of Russia.

The Central region covers coastal waters from Povorotny Cape to Gamov Cape. Man-made pollution is continuous here, especially in Amursky, Nakhodka and Ussuriisk bays, which have a high level of industrialization and agriculture development. The range of pollutants is wide here. Accumulations of pollutants in marine hydrobionts are apparent almost everywhere, and in some regions this makes them unsuitable for food and for technical purposes. Most of the coastal area is unusable for recreation purposes due to the great volume of waste waters discharged here. The therapeutic Sadgorod mud-baths in Amursky Bay are practically ruined.

The Southern region includes the coastal waters of Posjet Bay from Gamov Cape to the Tumen River. Water pollution is point-source here and is connected with the disposal of sanitary and, to a lesser extent, industrial waste waters. Build-up of pollutants in hydrobionts is not high. Under selective control they can be used for food. At the same time, constantly increasing pollution coming from the Tumen River basin has become characteristic here..

Coastal marine waters of the eastern shore of Korea are subject to pollution from wastewaters from the peninsula on the one hand and to the heavy impact of pollutants brought by the Korea current from Liaonung Bay on the other.

Water pollution with radioactive substances is a significant problem. The average level of pollution of the Japan Sea with Caesium-137 is 0.004 Bk l^{-1} (Preliminary Report). Recent information has shown that one of the main sources of radioactive pollution of seawaters in the north-west of the Japan Sea is solid radioactive waste (SRW). Bases of nuclear submarines (NS) and nuclear surface ships, ship repair facilities, points for harboring of written-off NS and on-land maintenance bases can be sources of marine pollution, too. Thus in 1985 in Chazhma Bay, pollution with the radionuclides occurred as a result of an accident on nuclear submarine K-431. An uncontrolled runaway reactor took place, with destruction of a core, release of fission products (together with effluents formed in the course of fire-fighting in the reactor compartment on the nuclear submarine that was holed) into the outside environment (the atmosphere and seawater of the bay) and transfer by wind of fine particles over the industrial zone (shipyards of the Navy Fleet) and further on over the coast of the Dunai Peninsula, bypassing settlement "Shkotov-22" (now Fokino).

Researches conducted in recent years have indicated that, in general, the situation in marine areas is not a major cause for concern, as the levels of Cs-137 and Sr-90 are within the background values 1.7-5.7 and 1.7-3.5 Bk m^{-3}, respectively. There were no essential differences between the levels of these elements in surface and bottom layers of water. In general, a ratio of ^{137}Cs to ^{90}Sr levels varies within 0.8 to 2.4, the average value being 1.54 ± 0.27, which agrees well with the ratio of levels of these radionuclides from global fall-out.

The general radiation contribution of fleet nuclear ships and support points in the Gulf of Peter the Great does not exceed 0.1%.

As a result of mixing processes in the upper layer (to 20-50 m) of sea water, radionuclides from global fall-outs become diluted: in surface run-off their concentrations are much higher which leads to their higher content in areas of river inflow. According to published data, in an area of wastes disposal the content of ^{137}Cs in water is 150-300 times more than the background level. Within 6-10 minutes the content of ^{137}Cs drops to a norm due to dilution.

Water pollution of the Japan Sea varies markedly in different parts. Most contaminated are coastal waters in the south of the Primorskyi Krai and the Korean Peninsula.

Ecological problems and their causes

In the Russian section of the Sea of Japan basin, major zones with heavy ecological load include:

- Peter the Great Gulf (primarily, Amursky Bay) and some areas of its watershed basin, including Ussuriisk City;
- the Rudnaya River basin.

Amursky Bay

Amursky Bay is subject to an anthropogenic load of five administration regions in the Primorskyi Krai - Ussuriisky, Nadezhdinsky, Oktyabrsky, Khasansky, Ussuriisk City and the western part of Vladivostok. Apart from this, waters of the Razdolnaya River bring here pollutants from some territories in the Heilunsian Province (China).

According to official information, more than $120x10^6$ m^3 of waste waters (including about $118x10^6$ m^3 of industrial waste waters, $118x10^3$ m^3 of waste waters from ports and 3,127 $x10^3$ m^3 of agricultural waste waters) are discharged here annually. Of this quantity nearly $78x10^6$ m^3 are untreated and more than 26 $x10^6$. m^3 are inadequately treated. Only $9.875x10^6$ m^3 or 8.1% of waste waters are treated properly. The main sources of pollutants are concentrated discharges of waste waters, flow from polluted surfaces of watersheds during rainstorms and snow melting, and scattered discharges into the sea. There are 27 wastewater outfalls into coastal waters of the bay with a total discharge (by expert estimations) of at least 130,000 m^3 a day (excluding the Razdolnaya River flow).

By expert estimations (TINRO, A.A. Ogorodnikov pers. comm.) wastewaters bring into Amursky Bay about 104,690 tonnes of organic substances (for BOD full), 110,050 tonnes of suspended matter, 1,540 tonnes of fats, 880 tonnes of petroleum products, 980 tonnes of SPAV, 4.6 tonnes of phenols and 1.2 tonnes of pesticides.

Pollution of natural areas is officially assessed by observations at a network of Roskomgidromet stations. Table 2 summarises data for Amursky Bay taken from the Roskomgidromet "Quality Yearbook of marine waters by hydrochemical parameters" for several years. It is seen that from time to time the maximum admissible concentrations (MAC) are exceeded 2-38 times for all controlled parameters of the bay water. And for phenols the MAC is 3-4 times higher practically all the time. The order of MAC levels being exceeded is: petroleum hydrocarbons > phenols > synthetic surface > active substances.

Table 2. Chemical pollution of Amursky Bay (Roskomgidromet data).

	Year	1986	1987	1988	1989
Petroleum	average	0.03	0.04	0.03	0.02
hydrocarbons, mg l^{-1}	maximum	0.57	0.40	4.61	0.20
Phenols,	average	0.03	0.001	0.003	0.004
mg l^{-1}	maximum	0.036	0.008	0.025	0.017
SPAV,	average	0.01	0.08	0.04	0.07
mg l^{-1}	maximum	0.37	0.28	0.116	0.15
DDT,	average	8.9	2.6	6.5	1.8
mg l^{-1}	maximum	97.2	35.0	251	39.5
Oxygen,	average	9.16	9.48	9.05	9.53
mg l^{-1}	maximum	1.90	1.54	2.04	3.47

The oxygen regime in the bay waters in a warm season is satisfactory. However, in July-September the content of dissolved oxygen is approximately halved. The ratio of background concentrations of suspended matter in coastal (Amursky Bay) and oceanic waters enables assessment of an anthropogenic effect:

- dissolved forms of heavy metals Pb (93) Co (19) Ni (6.1) Cd (5.9) Cu (1.9) Ag (1.6) Zn (1.0);
- suspended forms of heavy metals Cd (115) Ag (63) Ni (54) Pb (42) Co (36) Zn (14) Cu (3.0).

Figures in brackets denote coefficients of HM concentrations in coastal waters in relation to oceanic waters. Elements are arranged by decreasing concentrations. The results indicate considerable pollution of this area with heavy metals. HM concentrations are especially high in suspended matter.

Analysis of the material assembled over several years has revealed some zones with higher concentrations of pollutants in coastal waters of the bay. Kirpichny Zavod Bay is most severely affected by anthropogenic load, receiving metals with waters of the Pervaya and Vtoraya rivers and from sewage outlets. In this region there were also recorded high concentrations of cadmium, zinc and petroleum hydrocarbons, a high coverage of the water surface with films of organic pollutants, and presence of representatives of pathogenic microflora. Bottom sediments here contain high concentrations of petroleum hydrocarbons and such heavy metals as cadmium, zinc, mercury and others.

A geochemically abnormal zone in respect of some metals (Pb, Zn, Cu) is found in bottom sediments in the vicinity of the Egersheld Cape where bottom sediments, taken from Zolotoy Rog Bay in the course of bottom dredging works, are dumped.

The incoming pollutants interfere with biogeochemical cycles of elements controlling the ecosystem in Amursky Bay. To assess changes in the bay ecosystem due to anthropogenic impacts, observations were carried out on structural and functional characteristics of its various biocenoses. Pooling of the material obtained by the institutes of the Far-Eastern Branch of RAS and TINRO enabled the following conclusions:

1. In the period between 1925-1933 and 1970-1972 the bay area, with depths up to 80 m, was subject to deep restructuring of bottom communities, with the replacement of highly productive species of marine flora and fauna by silt-loving ones. In the recent four decades a general reduction of diversity

was witnessed. The average biomass of hydrobionts in the bay became three times less, while areas inhabited by communities with low biomass became 28 times more.

2. Sea urchins (gray and black), which are good indicators of a water quality, have completely disappeared from bay areas with a higher level of heavy metals and petroleum hydrocarbons in water and bottom sediments (an area of the Vtoraya Rechka River, outfall of waste waters on the De-Frize Peninsula). In areas with lower pollution levels, reproductive functions of animals are damaged.
3. Surveys of algal distribution on various parts of the bay coast have shown that in the recent decade the species that demand clean water have practically disappeared and have been replaced with *Ulva* species that can live in water with a lower content of organic matter and under worse lighting conditions.

The Amursky Bay ecosystem is decaying. To relieve the anthropogenic load on Amursky Bay, it will be necessary to carry out a wide complex of organizational and technical measures that will demand considerable capital investments, which will require changes in the structure of industrial complexes in Vladivostok and Ussuriisk and agriculture in the Razdolnaya River basin. In the past 3-4 years some improvement of the ecological situation in the bay was observed, but this is a temporary event connected with economic decline, and now with optimization of nature management in the watershed.

Rudnaya River valley

In the river runoff the share of technogenic compounds exceeds 70% of the whole ion runoff: for SO_4 90%, F 85%, B practically 100%. In the Rudnaya River mouth, as a result of dilution with inflowing water, the level of technogenic macroelements in water is about 40-50%, and microelements: Zn 90%, As and Pb 80%, Cu and Sn 75%. Therefore, pollution of surface waters makes them unsuitable for use, and the Rudnaya River has completely lost its fishery significance.

The sickness level in the Dalnegorsk region is 1.2 times higher than the territory average. Analysis of sickness has revealed frequent occurrence of such diseases as cancer of lymphatic tissue and acute infections of respiratory organs. Prolonged impacts of pollution of atmospheric air and other components of the biosphere has a cumulative effect resulting in damage to the human system.

From the above it follows that health of the population living in the Rudnaya River valley demands urgent measures for its improvement.

The Sea of Japan basin is subject to ever-increasing technogenic load of nature management not only on its territory, but on neighboring territories that are closely connected with it via a system of marine currents and aerial transfer. Improvement of the ecosystems of the region is possible only if regional development follows a concept of steady development. For this purpose it is necessary to establish a system of protected natural territories that will help not only preserve a genetic fund of natural ecosystems, but will become a basis for their restoration in territories that are now destroyed by a man, partially or completely.

5.14 Island based catchments: the Taiwan example

Chen-Tung Arthur Chen and James T. Liu

Taiwan is located in a subtropical region with the Tropic of Cancer traversing the southern part of this island. The north-east monsoon prevails from October to March when only 20% of the annual precipitation falls, while the south-west monsoon, which prevails from April through September, includes typhoons and thunderstorms which bring 80% of the annual precipitation. The average annual rainfall between 1949 and 1990 was 2,515 mm. With an area of 36,000 km^2, Taiwan has a total annual rainfall of 90.5×10^9 m^3.

The area of steep mountain terrain above 1,000 m elevation covers 32% of the island with 100 peaks exceeding 3,000 m. Hills and terraces between 100 and 1,000 m elevation comprise 31% of the island, while alluvial plains below an elevation of 100 m cover the remaining 37%. Taiwan has 21 principal rivers, 29 secondary rivers and 79 ordinary rivers (Water Resources Bureau 1998; Water Resources Planning Commission 1969-1995). Water quality data including dissolved oxygen, biochemical oxygen demand, suspended solids, ammonia, pH, turbidity, conductivity, chlorinity, temperature, Cd, Pb, Cr, Cu, Hg, Zn, *E.coli*, chemical oxygen demand and total phosphorus content are available for many stations at http://alphapc.epa.gov.tw.

Owing to their small catchment area, although the material fluxes are not high, their discharges per unit area can be rather large. For instance, the steepness and high rainfall, coupled with deforestation and road construction, have made many rivers rather muddy indeed. Table 1 summarizes the top 20 rivers worldwide in terms of sediment yield (T km^{-2} yr^{-1}) for rivers originating from elevations above 3,000 m, with their world ranking. This ranking includes seven Taiwanese rivers.

Table 1. Top 20 rivers in terms of sediment yield for rivers rising above 3,000m.

River	Yield (world rank), T km^{-2} yr^{-1}	Unit-area runoff (10^3T km^{-2} yr^{-1})
Choshui	20,000 (3)	1,900
Peinan	14,800 (6)	2,350
Kaoping	11,000 (11)	2,700
Aure (New Guinea)	11,000 (11)	?
Layang	8,200 (15)	2,900
Taan	6,300 (20)	2,000
Tanshui	4,100 (24)	2,200
Tachia	2,900 (33)	2,050
Purari (New Guinea)	2,600 (35)	2,500
Fly (New Guinea)	1,500 (43)	1,300
Yellow (China)	1,400 (65)	77
Magdalenc (Columbia)	920	990
Brahmaputra (Bangladesh)	890	?
Irrawaddy (Myana)	620	995
Ganges (India)	530	?
Indus (Pakistan)	260	245
Yangtze (China)	250	460
Amazon (Brazil)	190	100
Colorado (USA)	190	32
Orinoco (Venezuela)	150	1,100

Data taken from GESAMP (1994)

Table 2 summarizes the top 20 rivers in terms of sediment yield for rivers with a unit-area runoff exceeding 1.8×10^6 T km^{-2} yr^{-1}. Despite a clear correlation of the yield with the unit-area runoff, the relationship is not linear. For instance, the top-ranked river in unit-area runoff (8.9×10^6 T km^{-2} yr^{-1}), the Hokitika River in New Zealand, ranks only fifth in terms of sediment yield. The distant second- and third-ranked rivers in unit-area runoff (6.5×10^6 and 6.0×10^6 T km^{-2} yr^{-1}, respectively), the Cleddau and the Haast Rivers also in New Zealand, rank eighth in yield. The twentieth-ranked in unit-area runoff, the Karamea River, again in New Zealand, ranks extremely low in the yield.

Table 2. Top 20 rivers in terms of sediment yield for rivers with a unit-area runoff exceeding 1.8×10^6T km^{-2} yr^{-1}

River	Yield (world rank), T km^{-2} yr^{-1}	Unit-area runoff (world rank) (10^3T km^{-2} yr^{-1})
1. Tsengwen	26,000 (2)	2,000 (16)
2. Choshui	20,000 (3)	1,900 (18)
3. Hokitika (N.Z)	17,000 (5)	8,900 (1)
4. Peinan	14,800 (6)	2,350 (13)
5. Hualien	13,500 (7)	2,700 (7)
6. Cleddau (N.Z)	13,000 (8)	6,500 (2)
6. Haast (N.Z)	13,000 (8)	5,970 (3)
8. Hsiukuluan	11,000 (11)	2,700 (7)
8. Kaoping	11,000 (11)	2,700 (7)
10. Lanyang	8,200 (15)	2,900 (5)
11. Taan	6,300 (20)	2,000 (16)
12. Linpien	5,400 (22)	2,600 (10)
13. Tanshui	4,100 (24)	2,200 (14)
14. Wu	3,450 (31)	1,850 (19)
15. Tachia	2,100 (33)	2,050 (15)
16. Purari (New Guinea)	2,600 (35)	2,500 (11)
17. Rakaia (N.Z)	1,600 (42)	2,400 (12)
18. Tungkang	1,300 (45)	3,250 (4)
18. Pamanga (Philippines)	1,300 (69)	1,800 (20)
20. Karamea (N.Z)	320	2,900 (5)

Data taken from GESAMP (1994)

Table 3 lists the top 20 rivers worldwide in terms of sediment yield. Twelve rivers in Taiwan are ranked, highlighting the importance of small catchments. Milliman and Syvitski (1992) pointed to the importance of rivers on high islands such as Taiwan to the global sediment flux to the oceans. Many of these islands are located on active tectonic belts. Complex interplay between tectonic processes like uplifting, land subsidence, and riverine sediment supply all influence the development of these islands' coastlines (Liu *et al.* 1998).

The largest river in Taiwan, the Kaoping River in southern Taiwan, has a drainage area of 3,257 km^2, a mean annual runoff of 8.46×10^9 m^3, and a suspended sediment discharge of 3.61×10^7 T (Water Resource Bureau 1998). Due to the influence of the monsoon and episodic typhoons, the annual discharge of the Kaoping River is concentrated in the summer and early fall, culminating in August. On average, the amount of discharge in June, July, August, and September is equal to about 78% of the annual discharge of the river. The suspended sediment load estimated near the mouth of the river indicates that August also has the highest amount of suspended sediment discharge. Therefore, there are distinctive flood and dry seasons in the annual hydrological cycle of the river, which is typical for rivers in monsoonal southern Taiwan (Figure 1). On average, the monthly mean runoff of the Kaoping River in the flood season is one order of magnitude greater than that in the dry season.

Table 3. Top 20 rivers in the world in terms of sediment yield (T km^{-2} yr^{-1}).

River	Yield (world rank), T km^{-2} yr^{-1}
1. Erhjen	36,000
2. Tsengwen	26,000
2. Choshui	26,000
4. Waiapu (N.Z)	20,000
5. Hokitika (N.Z)	17,000
6. Peinan	14,800
7. Hualien	13,500
8. Haast (N.Z)	13,000
8. Cleddau (N.Z)	13,000
10. Cilutung (India)	12,000
11. Kaoping	11,000
11. Hsiukuluan	11,000
11. Aure (New Guinea)	11,000
14. Yenshui	10,000
15. Lanyang	8,200
16. Houlung	8,000
17. Angat (Philippines)	8,000
18. Cimanuk (India)	7,800
19. Pachang	6,750
20. Taan	6,300

Data taken from GESAMP (1994)

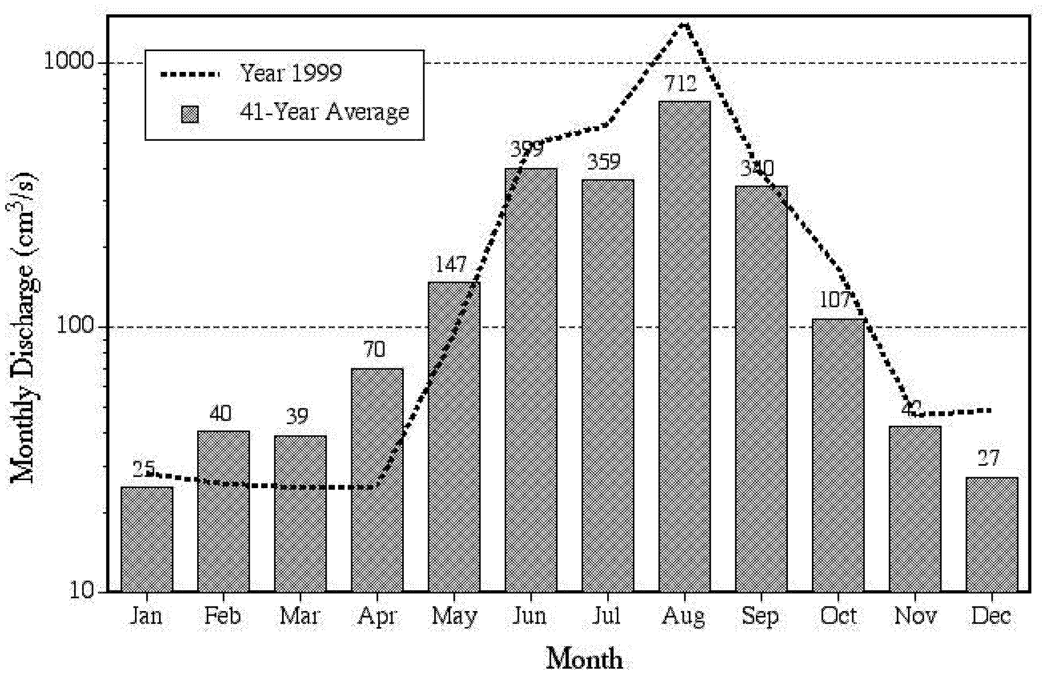

Figure 1. Mean monthly discharge of the Kaoping River and the monthly discharge for 1999 and the first three months of 2000 (data from Water Resources Bureau).

Subsequent close examination of the daily runoff and sediment content of the Kaoping River in 1999 and the first half of 2000 shows that several runoff and sediment discharge events took place during the flood seasons whose values are a factor of two above the average flood season level (Figure 2). Although these events are episodic, they nevertheless are times when extremes values occur. Therefore, the frequency of occurrence and the causes for these events need to be investigated further because of their significant environmental impacts.

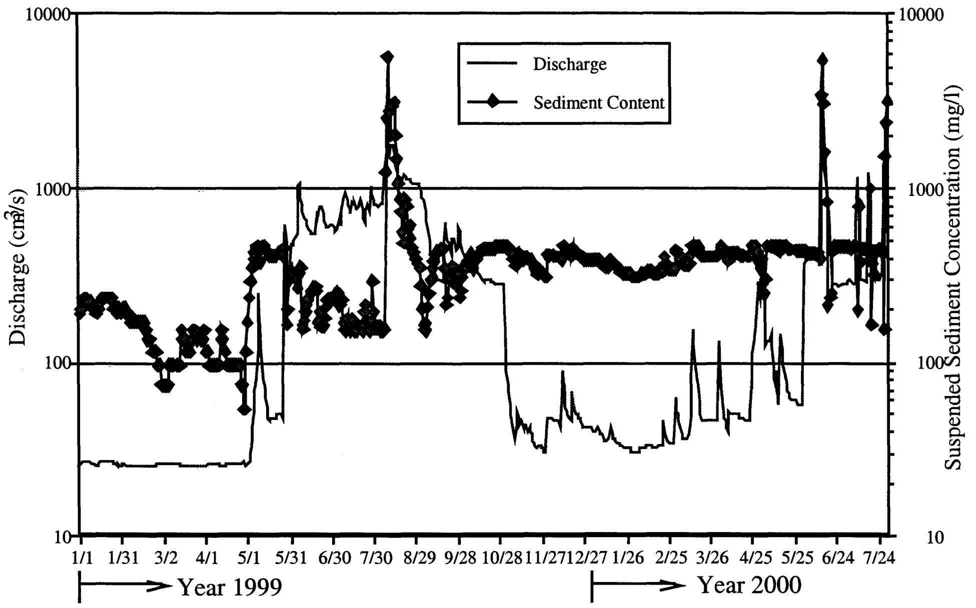

Figure 2. The daily runoff and sediment content observed at a gauging station about 34 km landward from the mouth of the Kaoping River from January 1, 1999 through July 31, 2000. The two vertical axes are in logarithmic scale (data from Water Resources Bureau).

This long-term trend, however, also shows inter-annual variabilities. For example, the mean monthly discharge for August 1999 is a factor of two greater than that of the 41-year average. This reflects the higher-than-normal precipitation in the river basin for the summer of 1999, which was a La Nina year. This anomaly is attributable to the regional effect of La Nina on the weather.

On the decadal time scale, a casual examination of the mean monthly runoff at the middle reaches of the river over the past 40 years (the longest continuous record for the river basin) reveals a decreasing trend in the maximum value of the runoff (Figure 3). No attempt has been made to correlate this trend with possible climatic factors such as the precipitation or human influence such as damming and irrigation. However, in general, climate change and anthropogenic activities more easily affect the hydrology of a small catchment.

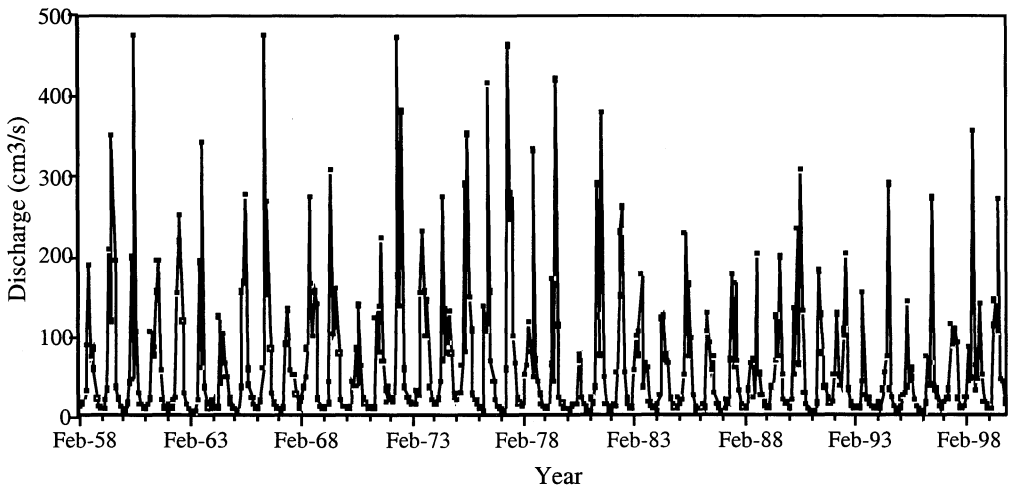

Figure 3. Long-term monthly discharge record from 1958 through 1998 at the Shin-fa Bridge gauging station in the middle reaches of the river basin (data from Water Resources Bureau).

Figure 4 describes the 24-year moving average of the instantaneous peak flood discharge on a tributary of the Kaoping River. The trend is obviously increasing. Figure 5, on the other hand, reveals that the instantaneous minimal discharge for the same river is decreasing. Since the precipitation pattern has no clear trend, the higher peak flow in the rainy season and lower minimal discharge in the dry season may be due to deforestation, which has reduced the forest coverage in Taiwan from around 90% to about 50% in the last century. Consequently, the flood and drought frequencies have both increased.

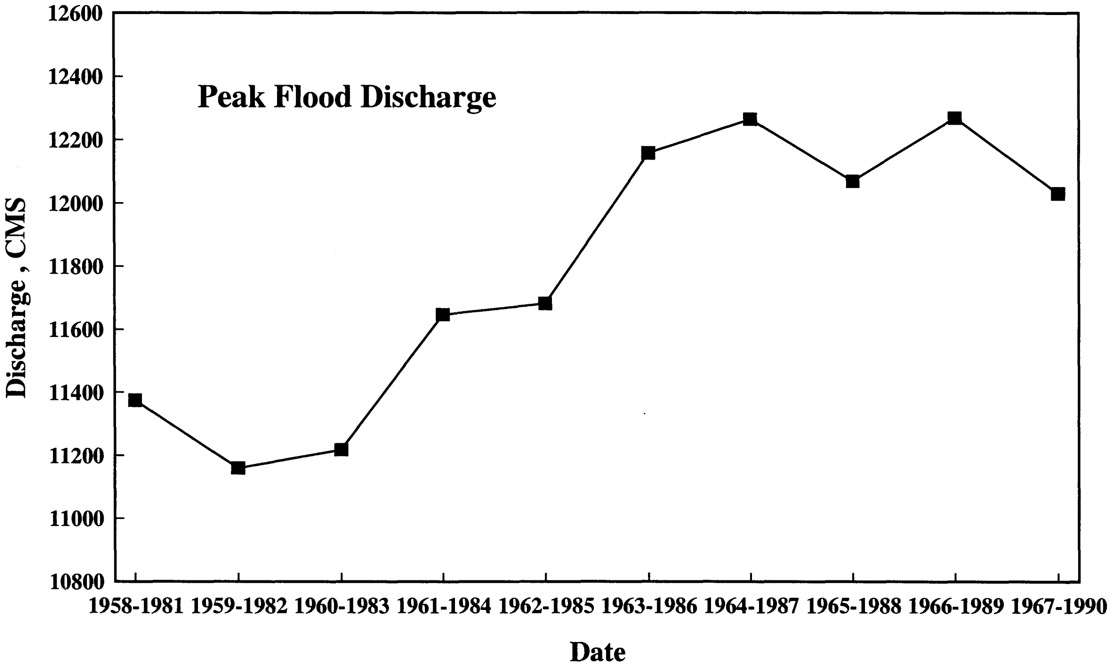

Figure 4. Twenty-four-year averages of the instantaneous peak flood discharge at the Shiu-fa Bridge gauging station between 1958 of 1990 (data from Water Resources Bureau).

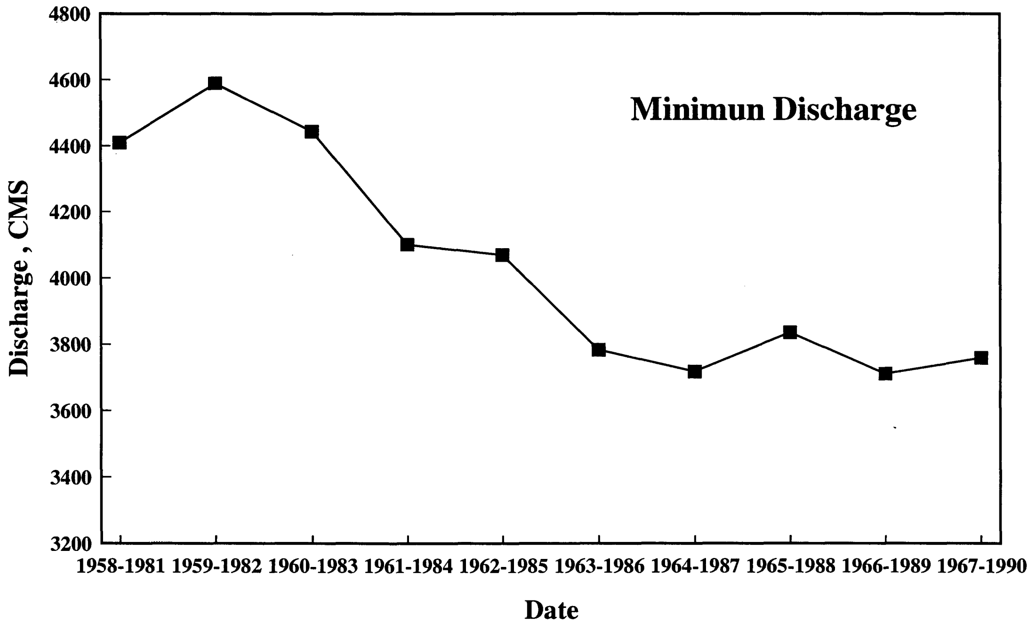

Figure 5. Twentyfour-year averages of the instantaneous minimum discharge at the Shiu-fa Bridge gauging station between 1958 of 1990 (data taken from Water Resources Bureau).

A spectral analysis of this record shows that the major variabilities (greater energy) have a periodicity of 12, 1.09, 0.92, and 0.52 years (Figure 6). We speculate that these periodicities correspond to the meso-scale regional climatic variability, and annual and intra-annual meteorological and hydrological variabilities of the drainage basin, respectively.

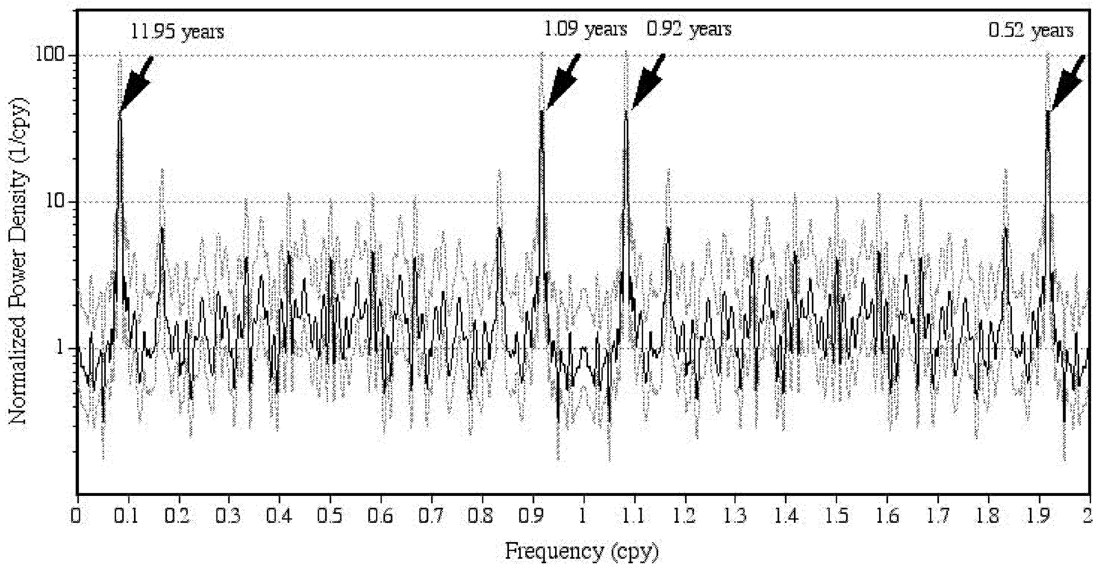

Figure 6. Spectral analysis result of the 40-year mean monthly runoff at Shin-fa Bridge. The frequency is in cycles per day. The two dashed curves mark the upper and lower bounds of the spectra at 90% confidence level.

Originally constructed to generate electricity, dams (>15 m) increasingly ensure the water supply during the dry season. Figure 7 summarizes the history of dam construction in Taiwan with the first recorded in 1885, currently totalling 40 with a combined size of 2.7×10^9 m^3.

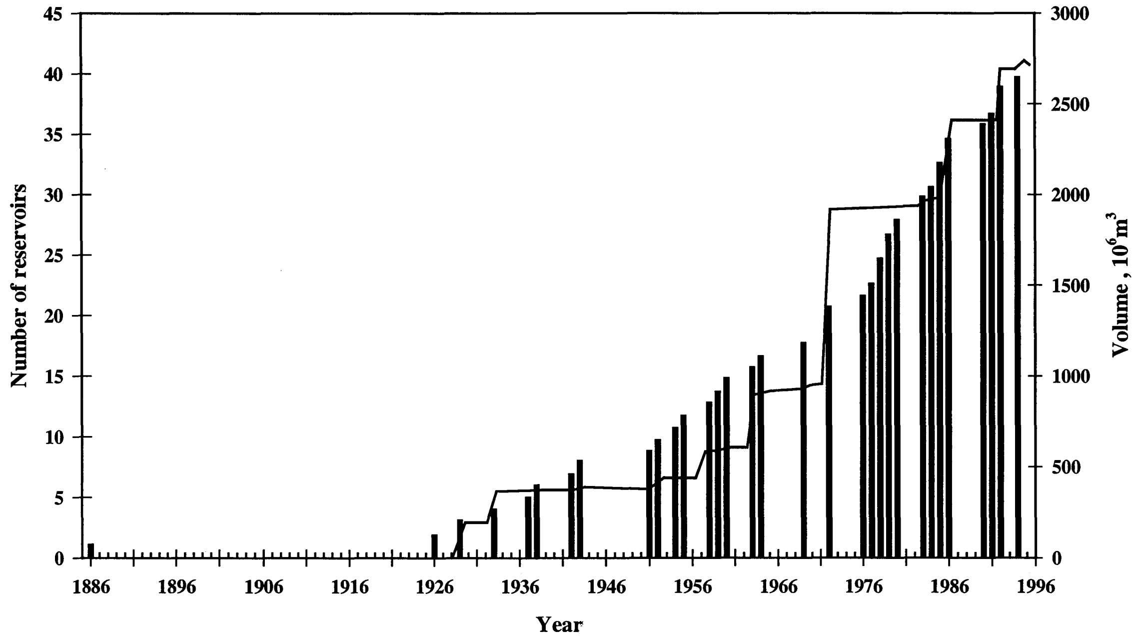

Figure 7. Number of reservoirs and their total capacity in Taiwan since 1886.

Sediment trapping by these dams has eroded many coastal deltas and beaches, which is compounded by the overpumping of groundwater. Cumulatively, 1,000 km^2 of the precious flat lands have subsided.

In summary, high mountainous rivers located in the tropical and subtropical regions of the world whose runoff and sediment content (sediment load) display:

(1) distinct dry and flood seasons in their annual hydrological cycle,
(2) the range of magnitude can span several orders of magnitude,
(3) the extreme values in the runoff and sediment content are controlled by episodic events that mostly occur in the summer (flood season),
(4) the strong variability of the runoff at annual and intra-annual frequencies suggest co-modulation by the monsoon and frontal movement. Since rivers are major conduits for land-derived substance, may it be sediments, nutrients, and pollutants, to the coastal sea, the environmental implications from these preliminary findings are that the great variability in the runoff and sediment load will inevitably impact the ecology and water quality in the estuarine and coastal area adjacent to the river mouth.

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5.15 Dams may impact fisheries even beyond the estuaries

Chen-Tung Arthur Chen

Rivers are the major conduits for the passage of water, nutrients, organic material and particulate matter from land to sea. Yet humans have being continuously altering river inputs into the ocean by their often unscrupulous use of the land. In many areas, the use of land for agriculture, forestry and mining, not to mention infrastructure and commercial development, has drastically increased the rate of terrestrial denudation. Levels in excess of ten times the natural rate of erosion are not uncommon. The effect of increased denudation is, however, not necessarily reflected in an immediate increase in the flux of particulate matter to the ocean. Rather, the eroded material may be stored for centuries or even millennia in upland areas before it finds its way to the ocean. For example, there was rapid erosion in the Piedmont of the central and southern Atlantic coast of the United States, starting in 1900, until soil conservation methods were introduced during the first half of the twentieth century. Even so, most of the eroded material still lies stored on hill slopes and on the floors of valley streams and not in the oceans.

On the other hand, river basin development, notably the construction of dams, has an immediate, profound impact on river inputs to the oceans. Dams trap sediments and regulate river flow which can result in a marked increase in the consumption of the river water. The completion of the large Aswan Dam on the Nile, among others, has drastically reduced freshwater outflow and this is central to substantial reductions in fish stocks in the connecting estuaries. Briefly put, dams block the down-stream transport of particulate matter which replenishes a delta and is an important source of nutrients and food for aquatic biota. Reduced sediment discharge contributes to the erosion of the delta, the transformation of the ecosystem as well as to the starvation of fishes. The more subtle effects, however, go far beyond the delta and estuaries.

In the case of the Three Gorges Dam, despite a large riverine input of nutrients to the East China Sea (ECS), only a small fraction (7% for P and 33% for N) of the total external nutrient supply that is required to support new production actually comes from that input. It is now clear that the major nutrient supply stems from the on-shore advection of the subsurface Kuroshio waters (Chen 1996; Chen and Wang 1999).

Since there is not so much nutrient outflow from the rivers, disruption of flow from the dam would not have a great effect on the not-so-important riverine nutrient flux to the ECS. Yet the completion of the Three Gorges Dam on the Yangtze River is likely to result in diminished productivity in the ECS, home to the largest fishing grounds in the world. This is because the decreased water flow would reduce cross-shelf upwelling, which is the major source of nutrients to the shelf. As a result, disruption of water flow would indeed reduce the important flux of nutrients from upwelling. For instance, cutting back the Yangtze River outflow by a mere 10% will reduce the cross-shelf water exchange by about 9% because of a reduced buoyancy effect, and, at the same time, it will cut the onshore nutrient supply by nearly the same amount. It can therefore be expected that primary production and fish catch in the ECS will decrease proportionately (Chen 2000).

The major dams in Asia are given in Table 1. From a global perspective, 60% of the largest 227 rivers are strongly fragmented by dams, diversions and canals. Large dams have increased sevenfold in number since 1950 and by the early part of last decade more than 13% of the global river flow to the sea had been dammed or diverted. This figure may exceed 20% within a few decades (Revenga *et al.* 2000). Most affected will probably be wide shelves with large riverine inputs. Approximately 40% of the fresh water and particulate matter entering the oceans is transported by the ten largest rivers, and this is in the form of a buoyant plume on the open shelves. These shelves face diminished fish production when damming reduces freshwater outflow and the buoyancy effect.

In isolated basins, such as the Black Sea, another danger can not be overlooked. If all the major rivers leading to the Black Sea, namely the Danube, Dnieper, Don, Rioni and Sakarya, were completely dammed, the decreased freshwater flux to the Black Sea could reduce the brackish surface mixed layer, which could lead to a shoaling of deeper waters rich in highly toxic hydrogen sulphide. This would undoubtedly have major environmental repercussions on the sea and all of the bordering countries.

Table 1. Major dams in Asia.

Name	Country	Year completed	Capacity(10^6 m^3)
Baishan	China	1984	4,967
Dongjiang	China	1989	8,120
Gezhouba	China	1992	1,580
Liujiaxia	China	1968	5,700
Longyangsia	China	1986	24,700
Wuijiangdu	China	1981	2,140
Yuccheng	China	1970	1,220
Balimela	India	1977	3,610
Bhakra	India	1963	9,621
Hirakud	India	1957	8,105
Idukki	India	1974	1,996
Pung Beas	India	1974	8,570
Ukai	India	1972	8,511
Mangla	Pakistan	1967	7,252
Tarbela	Pakistan	1976	13,690
Thac Ba	Vietnam	1971	3,600
Hoa Binh	Vietnam	1991	9,450
Tri An	Vietnam	1985	1,056

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5.16 The impact of human activities on Vietnamese rivers and coasts

Tran Duc Thanh, Dinh Van Huy, Van Lap Nguyen, Thi Kim Oanh Ta, Masaaki Tateishi and Yoshiki Saito

Introduction

The Vietnam shoreline stretches more than 3,200 km. The area of coastal waters 50 m deep or less is about 206,000 km^2, including 1,600 km^2 occupied by more than 3,000 islands. The Vietnamese coastal zone can be divided into four natural parts: the Tonkin Gulf, the central coast, the south-east coast and the Siam Gulf. Along the coastline, 114 small and large rivers have their mouths, of which the largest is the Mekong River and the second largest is the Red River. Water and suspended sediments from these two rivers greatly influence the coastal waters of many countries in Southeast Asia. In addition to estuaries associated with the river mouths, there are also many bays and lagoons that have resulted from the natural interaction between sea and land. Because of the high productivity of ecosystems such as estuaries, lagoons, mangrove forests, coral reefs, and seagrass beds, the Vietnamese coastal zone is high in biodiversity. About 11,000 aquatic and more than 1,300 island species inhabit the coastal zone, including many rare and precious endemic species. Because of the presence of rich natural resources and other favorable natural conditions, the coast is a zone of active development. Recently, there have been dramatic changes in terrestrial ecosystems of the coastal environment because the natural interactions between the land and the sea have been modified by human activities in both the coastal zone and in the watersheds of the rivers.

Setting

The Vietnamese coast is located in a tropical monsoon zone that experiences two seasons. The NE monsoon season from October to April is characterized by a prevailing north-easterly wind, and the SW monsoon season from May to September by a south-westerly wind. The mean wind velocity is 2.5-5 m s^{-1}, and the maximum velocity is 30 m s^{-1} during the NE monsoon and 50 m s^{-1} during the SW monsoon. The mean temperature is from 22.6 to 27.2°C, increasing southward. The mean annual rainfall is between 1,000 and 2,400 mm, with the least precipitation occurring along the central coast. During the period from 1975 to 1995, the coastal zone was struck directly by an annual average of 2.52 typhoons and 2.2 tropical low atmospheric depressions. The number of typhoons increased during the latter part of that period; for example, an average of 2.8 typhoons a year was recorded from 1991 to 1995. The irregularity of the typhoons also increased. The mean wave height was between 0.5 and 2.0 m measured at different sites. Maximum wave heights of 4.5 m during the NE monsoon and 7.5 m during the SW monsoon season have been recorded. The coastal tide consists of diurnal, semi-diurnal and mixed types, with a range from 0.5-4.0 m. The tidal range is high in the Mekong and Red River estuaries. In the western coastal zone of the Tonkin Gulf, the current velocity is small, about 10-15 cm s^{-1} with clockwise circulation during the SW monsoon season and counterclockwise circulation during the NE monsoon. Along the central coast, the current circulates counterclockwise with a great velocity of 30-70 cm s^{-1} year round. Along the southeast coast, the current flows southward with a velocity from 10-30 cm s^{-1}. Along the Siam Gulf coast, the current velocity is only 6-12 cm s^{-1}; it flows to the north-west during the NE monsoon season and to the south-east during the SW monsoon. Three areas of upwelling exist in the Vietnamese coastal zone. The largest is along the central coast, and the second largest is offshore of the Mekong estuary. In the Tonkin Gulf, the site of the upwelling changes according to the season; it lies near the south-west gulf coast during the SW monsoon season and is located in the center of the gulf during the NE monsoon (Ministry of Fishery 1996). Storm surges, which pose a danger to the coastal inhabitants, have amplitudes from 0.5 to a maximum of 3 m along the western coast of the Tonkin Gulf and an amplitude of 1.4 m in average along the central and south coasts (Ninh *et al.* 1992). A sea-level rise has been recorded at some coastal sites. For example, at Hon Dau station (Red River Delta), a rise averaging 2.24 mm yr^{-1} was observed from 1957 to 1989 (Thuy and Khuoc 1994).

Every year rivers discharge into the Vietnamese coastal zone about 880×10^9 m^3 of water and $200\text{-}250 \times 10^6$ t of suspended sediments, which are concentrated in the estuaries of the Mekong and Red rivers. The Mekong River catchment includes parts of six countries (China, Burma, Laos, Thailand, Cambodia and

Vietnam) and an area of 795,000 km^2, 9% of which is in Vietnam. Its annual discharge is 520.6x10^9 m^3 of water and 98x10^6 t of suspended sediments. The Red River catchment includes parts of two countries (China and Vietnam) and an area of 169,000 km^2, 51% of which is in Vietnam. Its annual discharge is 137x10^9 m^3 of water and 116x10^6 t of suspended sediments (Pho 1984; World Bank 1996).

Human activities

In both the coastal zone and the watersheds, human activities have influenced land-sea interactions and greatly impacted the environment and ecosystems in the coastal zone and adjacent areas.

The coastal land has a high population density; of Vietnam's total of 77 million people, 24% live in coastal districts. Along the coast, there are of 12 cities with populations over 100,000 and 37 smaller ports and harbours. There are 17 million people on the 17,000 km^2 of the Red River Delta (RRD), which also accounts for 20% of the rice production of Vietnam. Fifteen million people live on 39,000 km^2 in the Mekong River delta (MRD), where 50% of the nation's rice crop is grown. Annually, 0.8x10^6 t of fish are caught in coastal waters. Oil production is about 10x10^6 t yr^{-1}.

In 1943, there were 400,000 ha of mangrove forests, including 250,000 ha in the MRD alone, but by 1993 only about 170,000 ha of mangrove forests remained in the whole country (Hong and San 1993). Almost 200,000 ha of brackish aquaculture ponds have replaced the mangroves. Much of the tidal floodplain, including the mangrove marshes, has been reclaimed for agriculture. From 1958 to 1995, 24,000 ha of the tidal floodplain in the RRD were reclaimed. In this period, 985 ha yr^{-1} of tidal floodplain, mainly mangrove marshes, was reclaimed for agriculture or converted to brackish aquaculture ponds. The land area has expanded by only 361 ha yr^{-1} by seaward accretion during the same period.

During the last thousand years, a great system of dykes has been built to protect the plains and their inhabitants from river and ocean floods. In Vietnam there are 5,700 km of river dykes and 2,100 km of sea dykes, of which 3,000 km of river dykes and 1,500 km of sea dykes are in the RRD. The dykes divide the RRD into compartments, all of which are lower than the rising sea-level.

Coastal mining, for example the exploitation of coal deposits, sand and gravel for construction and heavy minerals, is an important activity that deforms the landscape, produces solid and liquid wastes and increases coastal erosion. Coastal mining operations in Quang Ninh Province annually dump 10x10^6 t of solid waste and 7x10^6 m^3 of liquid waste into the coastal zone. Upstream, forests have been destroyed by war, cultivation, logging and fire. Forest coverage decreased from 43% to 28% during the period 1943 - 1995 (Cuong 1997).

Vietnam has a cultivated land area of over 7x10^6 ha, 60% of which is paddy lands. A great volume of river water is needed for irrigation every year. For example, in 1990, 47x10^9 m^3 of water was used for irrigation, 7.4x10^9 m^3 in the RRD and 18.4x10^9 m^3 in the MRD (World Bank 1996). The demand for irrigation water is most pressing in the dry season. In the RRD during the dry season, the demand is from 25% to 50% of the river's water discharge, leading to a large decrease in water discharge to the coastal zone. In 1993, 2.1x10^6 t of chemical fertilizers were used in the cultivated lands, including 1.2x10^6 t urea, 793,000 t phosphate and 22,000 t potash. In 1988, 20,000 t of pesticides were used, including DDT, Lindane, Monitor, and Wofatox, and their use had increased to 30,000 t by 1994. Pesticide residues have been transported by rivers to the coastal zone where they may accumulate in the bottom sediments to high concentrations, such as in the RRD.

The rivers have been dammed to create many reservoirs in the watersheds and coastal plains for irrigation and hydroelectric power. Nine large reservoirs for hydroelectric power cover an area of 1,267 km^2. The largest, Hoa Binh, was built in 1987 on the Da River, which is the largest tributary of the Red River. The Hoa Binh dam occupies an area of 208 km^2 and holds 9.5x10^9 m^3 of water. Annually, 48x10^6 tons of sediments, equal to 83% of the suspended-sediment load, are transported into the reservoir and deposited. An even larger reservoir with an area of 440 km^2, to be named Son La, is planned for the upper Hoa Binh.

Annual domestic and industrial water demand is over $4x10^9$ m^3. A great volume of waste water, most of which is untreated, is dumped into the rivers and discharged into the coastal zone. From 657,000 to 820,000 m^3 d^{-1} of waste waters are produced by the industrial area of Ha Noi - Viet Tri - Hai Phong in the north and 550,000 m^3 d^{-1} by the industries of Ho Chi Minh City in the south. The $34x10^6$ m^3 wastewater yr^{-1} dumped into the Red River from the Viet Tri industrial site includes 100 t H_2SO_4, 40 t HCl, 300 t benzene and 25 t pesticide (Hoi *et al.* 1997). An initial estimate shows that every year 24,747 t PO_4^- and 35 068 t NO_3^- are transported into the coastal zone by the Red River's flow (Ninh *et al.* 1995).

Changes in the coastal environment and ecosystems

Recently, dramatic changes in the Vietnamese coastal environment and ecosystems have become obvious. However, quantitative analyses of these changes are few. The changes have been caused both by natural processes and human activities. Changes due to human activities can be global, as in the case of sea-level rise and unusual typhoons and meteorological disturbances related to human-induced global warming, or regional in scale, as from upstream deforestation and the construction of dams, or they can be localized in the coastal zone. In terms of land-sea interactions, human activities have had the following impacts on the Vietnamese coastal zone:

- Changed the supply and distribution of water, sediments, nutrients, and other materials.
- Changed the relationship and balance of dynamically interacting factors and processes.
- Changed the quality of coastal and marine environments by the increased loading and accumulation of pollutants.
- Caused the loss of coastal habitat.

These impacts have led to various negative consequences as explained below.

Increase in coastal risks

Coastal floods have increased in intensity and in frequency of occurrence. They are a consequence of the combined impact of upstream deforestation, heavy rains, sea-level rise, and the blocking of lagoonal inlets or river mouths by sedimentation. Coastal floods are especially severe and very dangerous when heavy rains and storm surges coincide during spring tides. Annual flooding in the MRD, which lasts from 2 to 6 months, mainly between August and October, inundates an area of more than $1.7x10^6$ ha and directly affects 9 million people. From 1926 to 1997, there were 23 heavy floods, of which those in 1991, 1994, and 1996 were particularly noteworthy. Floods along the central coast are very dangerous because of their sudden onset after heavy rains, a consequence of destroyed upstream forests, steep coastal landforms with longshore sand dunes and rapid blocking of lagoonal inlets and river mouths by sedimentation. Terrible floods in November 1999 along the central coast caused great loss of life and destroyed much infrastructure. Protected by the dyke system, the coastal lowlands of the RRD are flooded only by locally heavy rainfall. Floods in the RRD are especially dangerous when waves linked with storm surges break the sea dykes, as happened in 1955 and 1996.

Coastal erosion is of concern as it increases in scale and in the amount of resulting damage. Overall, 243 coastal sites covering 469 km of coastline have eroded at a rate of 5-10 m yr^{-1}. Among these sites, 96 have eroded more than 1 km of coastline each. The longest eroded site extends 60 km at Ganh Hao in the MRD and the second longest extends 30 km at Vanly in the RRD (Thanh 1995, Thanh and Huy 2000). In both the MRD and the RRD, which are known to be accreting, erosion has nevertheless occurred along one-fourth of the coastline of each delta. In the MRD, a stretch of 36 km of the Bo De coast has been eroding at a rate of 30-50 m yr^{-1}, and on average 112 ha of coastal land have been lost each year for the last century. In the RRD, the Vanly coast has been eroding at a rate of 10-15 m yr^{-1} during the last half century even though dykes and embankments protect this coast. An effective means of protecting the Vanly coast has been not found. At present, two sea-dyke systems have been built. Whenever the seaward dyke system is damaged by erosion, a new dyke system is built landward, and a great number of the inhabitants are forced to move. Coastal erosion has also long been a serious problem in the Bach Dang estuary in the north and in the Dong Nai estuary in the south, where population density is high. Along the central sandy coast, erosion localized with respect to both time and place happens suddenly. In general, the erosion rate is from 1-5 m yr^{-1}, but sometimes is as much as 10-15 m yr^{-1}. Typical eroded coasts are at Canh Duong, Thuan An and Phan Ri.

In the MRD, coastal deposition has occurred on the Camau Peninsula at a rate of 50-80 m yr^{-1}, with a maximum rate of 150 m yr^{-1}, and the peninsula has expanded seaward by a rate of 122 ha yr^{-1} during 1885-1985 (Nguyen *et al.* 1999). The RRD has expanded seaward 27 m yr^{-1}, with a maximum rate of 120 m yr^{-1}, and 360 ha land yr^{-1} have been added to this delta. In the deltas, deposition provides us with the precious resource of land. However, sedimentation is dominantly a risk, and this risk has become more extensive recently (Thanh 1995), with a particularly negative impact on the development of marine ports and harbors. Haiphong is a typical example; for more than a century, it was the biggest port in Vietnam, but recently big ships have not been able to reach the port due to the heavy sedimentation in its channel caused by the building of the Dinh Vu coastal dam.

Along the central coast, longshore sand drifts generated by wave action close up lagoonal inlets and river mouths leading to coastal floods, the freshening of saltwater lagoons, and the loss of water on its way to the sea. The closure of the Tu Hien inlet in Tam Giang Lagoon is an example.

Flood-related water freshening has caused the loss of the coastal fishery, including both the fishery catch and marine and brackish water aquaculture. Because of tidal pressures, saltwater now penetrates 30-50 km up the Red River and 60-70 km up the Mekong River.

More than 1.7 million ha of land have been impacted by saltwater intrusion in the MRD; this area is predicted to increase to 2.2 million ha in the near future if suitable management practices are not implemented. In recent decades, the one permil isohaline (salinity contour) has moved landward 4-10 km in the northeast part of the RRD. Due to gradual saltwater intrusion landward, salinity in every place in the MRD also has increased in the dry season and reaches its maximum in March and April every year. Comparing a contour line of 4 permil salinity during the last 20 years (1978-1998), approximately 20 km landward movement was recognized (Nguyen *et al.* 1999). Most of the Mekong water comes from the upper reaches in China during the dry season. A combination of factors such as the decrease in river-water discharge caused by dams and irrigation and the sea-level rise may have led to more saltwater intrusion, which is a serious problem not only for coastal agriculture, but for other sectors of the economy as well. Along the central coast, Thua Thien Hue Province, with a population of nearly one million, has urgently lacked fresh water for agriculture and domestic and industrial activities because of saltwater intrusion in the Huong River during the dry season.

Environmental pollution

For the most part, coastal and marine environmental quality is still rather good, although varying levels of pollution have been recorded at some sites due to contaminants produced by human activities in watersheds or in coastal or marine areas (Ninh *et al.* 1995; Hoi *et al.* 1997). Oil pollution is most serious. In waters close to the coast, the oil content exceeds the standard of 0.05 mg l^{-1} for fisheries and even the standard of 0.3 mg l^{-1} for domestic activities at some sites. For the offshore waters, an oil content of more than 0.05 mg l^{-1}, up to a maximum of 0.4 mg l^{-1}, has been recorded at 10% of the sampled stations. Pollution from heavy metals such as Fe, Zn, Cu, Cd, Hg, As, Pb is not yet widespread, but the concentrations of these pollutants may be increasing in coastal waters, sediments, and wildlife. Fe, Zn, and Cu pollution has been confirmed at several sites. Similarly, organic-matter pollution is distributed locally, but is heavy at some sites. In general, pesticide residues have been below standard limits, although evidence for their accumulation is widespread and they exceed standard limits in several places, for example, in the coastal zone of the RRD.

Eutrophication is a problem in southern Vietnam, where nutrients such as phosphate (PO_4^{-3}), nitrogen (NO_2^-, NO_3^-), and organic matter are produced as waste from domestic activities, agriculture, and aquaculture. The widespread occurrence of brackish water aquaculture diseases in the south may be related to eutrophication and to red tides. In 1996, the brackish water shrimp aquaculture industry in the MRD lost many thousands of Vietnamese dong due to the expansion of eutrophication and red-tide blooms. Some shellfish may be poisoned by toxic phytoplankton, but unfortunately no scientific studies of this problem have yet been conducted.

The unusual changes in suspended sediment distribution have caused turbidity at swimming and resort sites such as Doson Beach.

Decreases in biodiversity and living resources

The recent natural and human-caused changes to the coastal zone have led to the loss of such coastal habitats as tidal flats, mangrove marshes, beaches, seagrass beds, and coral reefs. The mangroves have been heavily damaged by agriculture, aquaculture, and logging and even by erosion. The beaches have been reduced by erosion and sand quarrying. Coral reefs and seagrass beds have been destroyed by turbidity, freshening of the water, strong typhoon waves and pollution. The coastal zone, especially estuaries, bays and lagoons, is the site of breeding and spawning grounds essential to the maintenance of fishery production. Pollution and loss of habitats in this zone have degraded living resources for coastal and offshore fisheries. Dams in the watershed have also obstructed the migration for spawning of some fish species, for example, *Clupanodon thrissa* and *Maerura reeversii,* so that these fishes are now rare. The breeding success of migrating fishes has been halved due to the dams in the Red River watershed. Combined with over-exploitation, the coastal changes have threatened the survival of many marine species, including 98 species are recorded in the Vietnam Red Book (Ministry of Fishery 1996).

The degradation of coastal ecosystems - water freshening, turbidity, eutrophication or nutrient loss, pollution, and loss of habitat - leads to the disruption of the ecological balance and to decreases in biological productivity and biodiversity.

The size of the catch from coastal and offshore waters has decreased where the fishing grounds have not been stable with respect to location and catching output. The marine fishery, which is mainly along the coast, has been faced with a decrease in living resources, while brackish water and marine aquaculture has begun to suffer from diseases caused by environmental changes and pollution.

Conclusion

Because of their rich natural resources and other favorable natural conditions, the Vietnamese coast and river valleys have become zones of active economic development and high population density. Human activities such as upstream deforestation and the destruction of mangrove swamps, dyke and dam building, channel dredging, agriculture, aquaculture and industrial and domestic activities in both the coastal zone and the river watersheds have strongly influenced the Vietnamese coastal and riverine environments.

In terms of the Land-Ocean Interactions in the Coastal Zone (LOICZ) programme, the impacts of these activities include changes in the supply and distribution of water, sediments, and nutrients; changes in the relation and balance of dynamically interacting factors and processes; and changes in the quality of the coastal and marine environments due to the increased use and accumulation of pollutants and loss of habitats. These impacts have resulted in coastal problems such as floods, erosion, sedimentation and saltwater intrusion becoming less predictable and more severe; environmental pollution from, for example, oil, organic matter, pesticide residues and, to varying degrees, heavy metals; and the degradation of ecosystems with accompanying decreases in biodiversity and fishery productivity.

These impacts are the result of human activities in other countries through which the Red, Mekong, and other rivers flow as well as of those in Vietnam. Similarly, not only Vietnam but other countries as well suffer the negative consequences to the coastal environment and its resources.

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5.17 Socio-economic drivers of changes in coastal areas of the Red River Delta, Vietnam

Nguyen Hoang Tri

Introduction

This paper is an extended summary of the SARCS/WOTRO/ LOICZ Project on Economic Valuation of Mangrove Conservation and Rehabilitation in the Red River Delta, Vietnam, among three other Asian countries Malaysia, Philippines and Thailand, during 1996-1999. During this project, a new approach was developed to model human-induced environmental change in the coastal zone. A basis for the linkage of biogeochemical or nutrient budget models with ecological process models and economic models was provided by guidelines from discussions during the project's workshops. It contributes directly to the goals of LOICZ Focus 4: 'to develop integrated models, scenarios and/or forecasts for specific area or system, encompassing both natural and social driving forces of change', and to the SARCS Immediate Objective 2: 'to integrate natural-social science assessment of changes in the coastal zones of the SARCS region'. The results of this study contribute to scientific-based management of the coastal zone as well as building local capacity in sustainable development with sound ecology of the region.

The study site

Covering an area of approximately 190,000 km^2 (including the Thai Binh River basin), the Red River Basin is shared by China, Vietnam, and Laos. Approximately 62,400 km^2 is occupied by the People's Republic of China (Yunnan Province); some 1,500 km^2 belongs to Laos PDR; and the remaining 117,000 km^2 is in Vietnam (see Figure 1). The Red River stretches over approximately 1,140 km (some 500 km is in Vietnam), and has three major tributaries: Da, Thao and Lo-Gam, flowing into the Gulf of Bac Bo (see map).

The rivers, which flow into the East Sea through the Red River Delta, have an annual discharge of approximately 90-100 km^3 yr^{-1} through their river mouths. The defined boundary of project includes three ecological zones: up-lands, delta and coastal areas. There are about 20 million people living in 19 provinces. The population density varies from 50 people km^{-2} in the mountainous areas to 2,000 people km^{-2} in cities. The average birthrate fell from 2.8 % in 1990 to 1.7 % in 1998. However, the population distribution by age group shows that the highest percentage (14-38% in mountainous areas and 11-12% in delta area) of the population pyramid belongs to ages 1-9. The exploitation patterns of natural resources and the relationship between nature conservation and economic development will in the future depend on this driving force.

From an environmental perspective, the ecological system of wetlands in the basin is of particular significance. There are 30 species of mangroves found in the delta, constituting some 30,000 ha of mangrove forests. There are three protected areas in the delta: Xuan Thuy Nature Reserve (for approximately 250,000 birds, including six internationally recognized rare or endangered migratory birds), Cat Ba National Park (for coral reefs, mangrove forests and the *T. Poliocephalus* monkey, which is endemic) and Halong Bay Natural Heritage. The delta is the nursery and spawning grounds for fish (207 fish species) and shrimps, particularly such commercially important shrimp species as *Penaeus merguiensis*, *P. monodon*, *P. orientaris* and *Metapenaeus ensis*. Due to its international importance, Xuan Thuy Reserve has been designated as a Ramsar site since 1988.

Threats to the basin wetland ecosystems include land-based pollution from the catchment to the delta rivers and coastlines, in particular agricultural development (rice cultivation), coastal industry and mining, upper watershed development and deforestation, aquaculture and tourism development. Otherwise, much of the mangrove forests have been converted into shrimp ponds and human settlements. The natural and human activities in the upper basin have strong impacts on the ecosystems of the lower basin, delta and associated coastal areas.

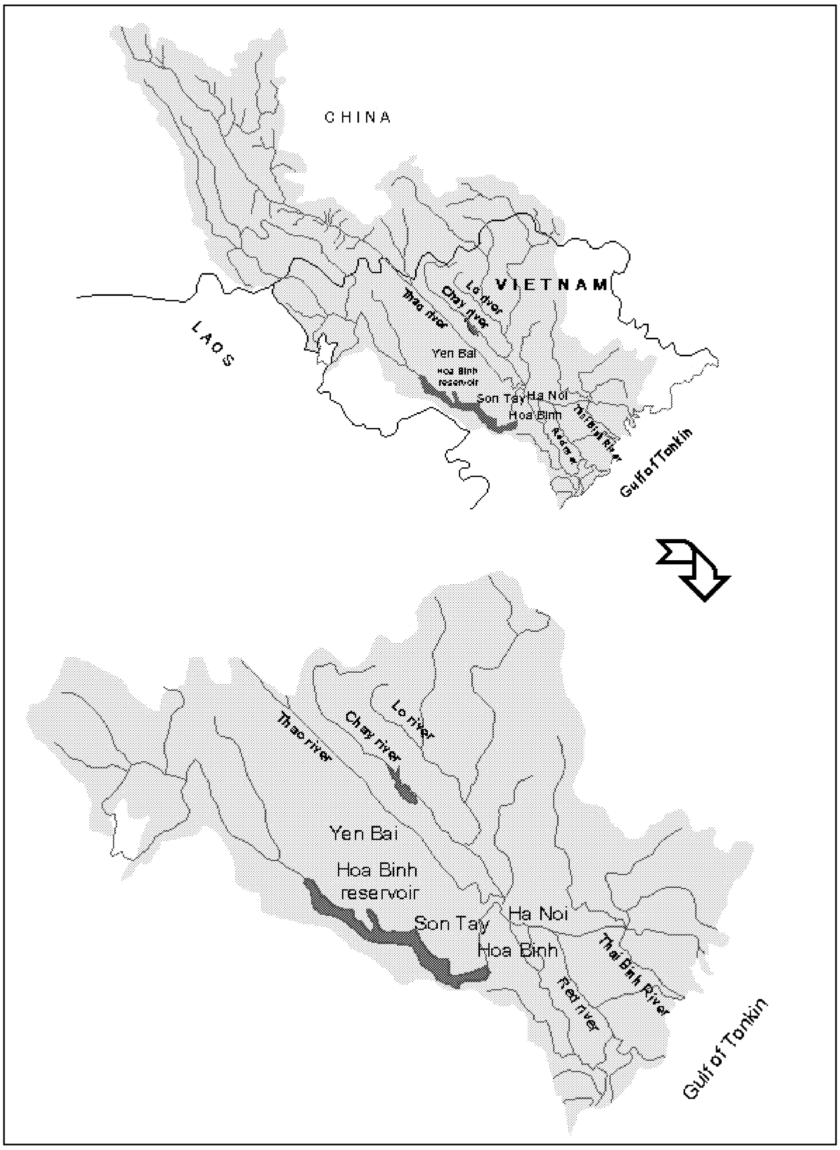

Figure 1. Map showing the Red River basin and the project location including 19 provinces of upland, delta and coastal areas in Vietnam.

Methods

The interaction between economic activities and environmental issues in the basin can be considered as:

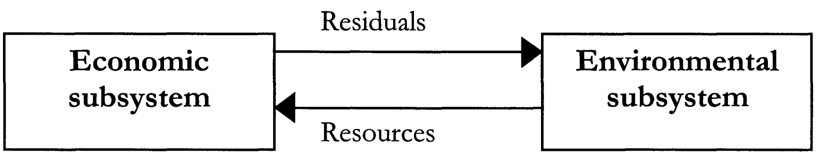

Figure 2. Conceptual integrated model for the interaction between economic activities and environmental issues in the coastal zone (from LOICZ, 1997a,b; McManus *et al.* 2001).

For estimating the impacts of economic activities to the environment of the basin in general and the coastal zone in particular, an Input–Output (IO) model was applied as described in Turner *et al.* (1998). The IO model presents almost major economic activities which take place in the basin economy (19 provinces) as flows of economic values between sectors.

The eleven sectors according to the World Health Organization (WHO) used in this analysis were defined to suit the local economy (WHO 1993). These are:

(1) agriculture,
(2) fishery/aquaculture,
(3) forestry and hunting,
(4) mining and quarrying,
(5) manufacturing 1 (heavy),
(6) manufacturing 2 (light),
(7) electricity and gas,
(8) water supply,
(9) construction,
(10) transportation, and
(11) other services.

The conventional IO table of the 11x11 sectors for the Red River Basin was initially constructed based on the General Statistic Office (GSO)'s national IO tables for 1995 and 1996. Proper adjustments was then effected, based on data generated from the basin survey. The conventional IO table and the Leontief inverse matrix are the main products of the component.

For estimating residuals generated from production and consumption, the economic- environmental coefficient matrix is constructed from a residual matrix that is largely measured in the field, and the given outputs. One element of this matrix is the total residuals generated per million VND (currency unit) of final demand. The change in impact variables due to a change in final demand is also estimated.

Prediction of the generated residuals due to different growth rates of national economy is also developed on the three scenarios of economic development, i.e. growth rate of GDP (%) .03; 6.08 and 7.4 for the Red River Basin (MOSTE 1994; GSO 1997).

Results and discussions

The IO models of economic activities, which take place in a regional economy based on flow of economic value between 11 sectors is presented in Table 1. The models are based on matrix tables where the non-leading diagonal element makes up the inter-sectoral flows.

Among them, the agriculture has a large value (over 21,898 thousand million VND per year) comparison with the rest sectors. This is relevant to the national economy where eighty percent of population living in rural areas. The development of this sector is basing on extensive from destruction of forests and intensive with large use of chemicals, both are effecting to environment to be qualified later.

Table 1. The estimated final demand in the IO table (in millions VND) in 1996.

Sectors	First demand	Consumption expenditure	Household consumption	Accumulat-ion	Export - import	Gross output	Final demand
1. Agriculture	5,590,984	12,244,273	12,244,273	-34,003	9,688,619	27,489,874	21,898,890
2. Fishery	912,815	799,315	799,315	-	-501,469	1,210,662	297,847
3. Forestry and hunting	561,619	464,664	464,664	7,077	730,478	1,763,838	1,202,219
4. Mining and quarrying	310,563	-	-	53,489	564,391	928,443	617,880
5. Manufacturing I (Heavy)	8,222,530	6,935,162	6,935,162	283,261	902,872	16,343,825	8,121,295
6. Manufacturing II (Light)	15,939,481	4,762,013	4,762,013	3,672,355	-12,044,297	12,329,552	-3,609,929
7. Electricity, gas	1,458,796	417,483	417,483	-	607,812	2,484,090	1,025,295
8. Waterworks and supply	78,690	162,927	162,927	-	66,722	308,340	229,650
9. Construction	800,485	-	-	12,414,711	-	13,215,196	12,414,711
10. Transport-ation	2,565,587	1,055,934	1,055,934	124,080	-822,241	2,923,359	357,772
11. Other services	6,639,821	26,272,122	12,292,178	261,296	-12,176,453	20,996,785	14,356,964
Intermediate consumption	43,081,370	53,113,892	39,133,948	16,782,266	-12,983,564	99,993,964	
Value added	56,912,594			16,782,297			
GI (gross input)	99,993,964						

The estimation of residual generation from economic activities based on the final demand and economic-environmental coefficient is presented in Table 2. Agricultural activities contribute 31,332 t nitrogen, 19,026 t phosphorus and 149,570,083 t suspended solids or 75-80 % residuals generated from agriculture sectors. The heavy industry (manufacturing 1) is only 3.4-4.2 % of the total and other services including household consumption contribute 11-15 %. The construction sector contributed 4-5.6 %. A regional IO model in the Philippines was utilized in conjunction with other models to examine, among other things, the impact of land-based environmental changes in the coastal environment of Lingayen Gulf (McManus *et al.* 1999). The IO analysis is therefore useful in integrating modelling in the coastal zone, primarily the spatial downscaling and the availability of data, particularly relating to environmental coefficients (Secretario 1995).

Production and environmental impacts from all sectors of economy are pervasive. Increasing the overall scales of economy activities increases the sector-specific production of pollutants and other waste products, known in economics as externalities (Ayres and Kneese 1969).

Table 2. Estimation of residual generation from economic activities based on final demand and economic-environmental coefficients.

	Final demand (MVND)	Nitrogen (t)	Total suspended solids (t)	Phosphorus (t)
Agriculture	21,898,890	31,332	149,570,083	19,026
Fishery	297,847	40	160,508	24
Forestry and hunting	1,202,219	267	2,130,987	109
Mining and quarrying	617,880	90	1,648,439	199
Manufacturing I	8,121,295	1,411	7,169,424	1,050
Manufacturing II	-3,609,929	(876)	(2,698,204)	(472)
Electricity, gas	1,025,295	93	448,977	54
Waterworks and supply	229,650	26	67,440	12
Construction	12,414,711	2,273	7,490,157	1,174
Transportation	357,772	61	193,024	30
Other services	14,356,964	6,227	22,292,439	2,975
Total		**40,943**	**188,473,275**	**25,123**

The scenario development is largely based on documents of national strategy for economic development (GSO 1996). These scenarios involve changes in final demand, and the resulting impacts on residual generation therefore determined. The breakdown for each sector in the basin area is analyzed by data available for 1996. The result is presented in Table 3, where the regional growth rates of 5.03, 6.08 and 7.4 (%) are broken down into in detail for 11 sectors. Four sectors: heavy industry, light industry, transportation and other services are predicted to develop in the next decade with growth rates of 7-10 % per year.

Table 3. Forecasting the growth rate (% yr^{-1}) of each sector using the scenarios of socio-economic development.

Growth rate of GDP (%)	Scenario 1 *5.03*	Scenario 2 *6.08*	Scenario 3 *7.4*
1. Agriculture	3.50	4.23	3.80
2. Fishery	1.50	1.81	1.20
3. Forestry and hunting	0.00	0.00	0.00
4. Mining and quarrying	1.80	2.18	1.00
5. Manufacturing I (Heavy)	8.70	10.52	8.00
6. Manufacturing II (Light)	7.50	9.07	9.00
7. Electricity, gas	3.50	4.23	4.00
8. Waterworks and supply	3.50	4.23	3.50
9. Construction	4.00	4.83	8.00
10. Transportation	8.00	9.67	8.00
11. Other services	7.50	9.07	8.50

From the scenarios of economic development, the increased nitrogen is also forecast as presented in Table 4. Therefore, continued growth in output and population is becoming unsustainable due to environmental damage. Appropriate policy measures demand a detailed understanding of the environment impacts of particular activities and hence the need to model the relationship between the economy and the environment. For this purpose, the model of interaction between the economy and the environment are useful. Orbeta *et al.* (1996) applied the methodology in a policy simulation study for the Philippines to analyze the resource and environmental and natural resource accounting framework (Mendoza 1994). The basic framework can be used to develop scenarios and estimate changes in the output of both monetary flows in the economy and environmental residuals.

Table 4. Forecasting the increased nitrogen generation (tonnes) from the scenarios of socio-economic development in the region.

Sectors	Present time (1996)	Scenario 1 (increased GDP 5.03%)	Scenario 2 (increased GDP 6.08%)	Scenario 3 (increased GDP 7.4%)
Agriculture	31,332	32,725.99	32,885.78	33,465.42
Fishery	40	42.19	42.40	43.14
Forestry and hunting	267	279.32	280.68	285.63
Mining and quarrying	90	93.80	94.26	95.92
Manufacturing I	1,411	1,473.27	1,480.47	1,506.56
Manufacturing II	(876)	(915.08)	(919.54)	(935.75)
Electricity, gas	93	97.30	97.78	99.50
Waterworks and supply	26	26.75	26.88	27.36
Construction	2,273	2,374.39	2,385.99	2,428.04
Transportation	61	63.21	63.52	64.64
Other services	6,227	6,504.00	6,535.76	6,650.95
Total	**40,943**	**42,765.15**	**42,973.96**	**43,731.41**

Conclusions

These models are developed using national IO tables and economic-environmental coefficients which are estimated through sectoral surveys. The impacts of alternative development scenarios on GDP growth rates and the residuals are estimated. These changes in the state of the environment may form a part of assessment under Driver-Pressure-State-Impact-Response (DPSIR) framework. However, the crucial step of processing and consumption of the environmental resources generating residuals which are returned to the environment and which may have undesirable economic, social or health effects, such as eutrophication and loss of habitats, has not been done yet.

The IO approach applied in this study relates to a regional matrix. It depends on the availability of data, particularly of the estimates of economic-environmental coefficients from each sector. The approach signifies the periodic flows of residuals where the coefficients can be estimated, but does not distinguish between those residuals, which are cumulative in the environment. Despite these limitations, the IO modelling framework can be used in integration of coastal change by demonstrating the impacts of scenarios of human driving forces or pressures in terms of GDP growth rates on the state of coastal zone through loading of residuals including pollutants and other materials.

Acknowledgements

We would like to thank LOICZ and SARCS for their continued support and interest, and WOTRO for their financial support. Our special thanks go to Dr. Renee van Kessel for her efficient and gracious administration of the project. We are also grateful to Mangrove Ecosystem Research Division, the Center for Natural Resources and Environmental Studies (CRES) of the Vietnam National University, Hanoi for their technical and staffs as well as administrative support and equipment.

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5.18 Relevance of riverine inputs and retention to the change of nutrient load into the coastal zone

Horst Behrendt

Eutrophication of seas and estuaries is mainly caused by increased nutrient loads from the land. A reduction of nutrient loads is often necessary for the sustainability of the estuaries and seas. Effective measures of nutrient reduction need knowledge of the amount and sources of loads. Rivers are the main carrier of nutrients from land to the sea. Emissions into river systems from different pathways (point and diffuse sources) have to be estimated. Depending on the pathway and the nutrient, different retention processes occur, which are characterized by different residence times and depend on soil and hydrogeological properties as well as on the hydrological and morphological conditions within the individual river systems.

Models which include at least parts of these complex interactions are to date rather scarce and mostly applied only to small catchments. Dynamic models for nutrient emissions do not exist for all pathways and cannot be applied yet to medium and large river basins.

The GIS-oriented Model **MONERIS** (**MO**deling **N**utrient **E**missions in **RI**ver **S**ystems) was developed for the estimation of nutrient inputs from various point and diffuse sources into German river basins larger than 1,000 km^2 for the periods 1983 to 1987 and 1993 to 1997. A detailed description of the model is given by Behrendt *et al.* (2000).

The basic input into the model is data on discharges, data on water quality of the investigated river basins and a Geographical Information System integrating digital maps as well as statistical information for different administrative levels.

Whereas the inputs of municipal wastewater treatment plants and direct industrial discharges enter the river system directly, the sum of the diffuse nutrient inputs into the surface waters is the result of different pathways realized by several runoff components (see Figure 1).

The distinction between the inputs from the different runoff components is necessary, because the concentrations of substances within the runoff components and the processes within these runoff components are very different. Therefore the MONERIS model takes seven pathways into account:

- discharges from point sources
- inputs into surface waters by atmospheric deposition
- inputs into surface waters from groundwater
- inputs into surface waters from tile drainage
- inputs into surface waters from paved urban areas
- inputs into surface waters by erosion
- inputs into surface waters by surface runoff (only dissolved nutrients).

Within the diffuse pathways, various transformation, loss and retention processes are identified. To quantify and forecast the nutrient inputs in relation to their cause requires knowledge of these transformation and retention processes. This is not yet possible through detailed dynamic process models because the current state of knowledge and existing data-bases is limited for medium and large river basins. Therefore, existing approaches of macro-scale modelling will be complemented and modified and if necessary attempts will be made to derive new applicable conceptual models for the estimation of nutrient inputs via the individual diffuse pathways.

An important step in the development of the individual sub-models was to validate these models by comparing the results with independent data sets. For example, the groundwater sub-model was validated with measured groundwater concentrations.

The use of a Geographical Information System provides the possibility for a regionalized estimation of nutrient inputs. The estimations were done with the same methodology for ca. 300 different river basins. The calculation was done for two time-periods: 1983 to 1987 and 1993 to 1997. The results of the two periods were compared with estimations by other authors and analysed for changes of nutrient inputs. These changes were estimated based on the different hydrological conditions as well as the same hydrological conditions in the two time periods. The assumption of unique hydrological conditions for both time periods can be used to identify the changes caused by anthropogenic activities.

The model was developed for German river basins and the time period 1993-1997. With changed input data but the same coefficients, this model was applied for the second time period 1983-1987. Recently the model was also applied to the river Oder and more than 30 sub-basins within this international river. Other more detailed model approaches developed for individual pathways and applied for the Odra river shows similar results.

One main result of the model application is that the retention and loss processes within the terrestrial and aquatic spheres show great variation depending on the hydrological, geochemical and geophysical situation within the basins. The influence of these retention processes on the transformation of the nutrient inputs to the load at the outlet of a river can be in a range from about 40 to more than 95% as the total anthropogenic nutrient inputs to the terrestrial (atmospheric deposition and nutrient surplus in agriculture) and aquatic spheres (sum of all nutrient emissions from point and diffuse sources to the river system according to Figure 1). Further, the time delay between the anthropogenic use of nutrients and the response in the river system can be in the order of years to decades. People influence not only nutrient uses but also the hydrological and geophysical conditions in the river basins (e.g., construction of reservoirs, establishment of tile drainage, straightening of rivers). These measures can have at least as great an influence on the change of the nutrient loads in rivers as the change of the nutrient uses.

Scenario calculations have shown that relatively small changes in the retention potential can affect in some regions the nutrient load more than large changes of nutrient uses by people. Climate changes and geochemical processes will change the retention potential in the future. Therefore, the focus of the further research to explain and model the causes of the change of the nutrient load in river systems needs both more precise knowledge of the nutrient uses and of the retention processes in the terrestrial and aquatic field.

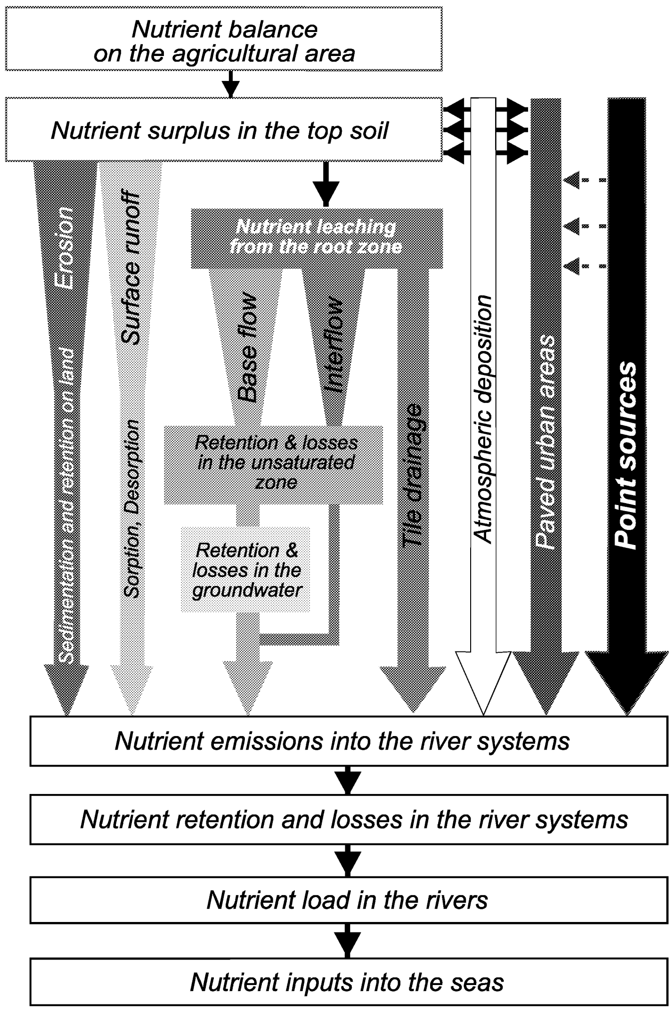

Figure 1. Pathways and processes in MONERIS.

5.19 Utilizing GIS to relate spatial and temporal dynamics of the emergent East Asian coast

Casey J. McLaughlin

Abstract

The natural sedimentation rates and geomorphology of the Yellow (Huang He) River are well-documented, but they have not been related across time and space in a GIS and existing models fail to address human influences. The Yellow River, for example, no longer flows into the ocean for a large portion of the year, due to increased water consumption by industry, agriculture and a growing population in the last 20 to 30 years. The Yellow River delta's shift from rapid accretion (fueled by its traditionally large sediment load) to coastal erosion is a dramatic shift in the development of coastal morphology with profound societal repercussions. Historical maps and remotely sensed data will be used to create a GIS model to determine impacts of river change on the East Asia coastline using a multi-scale approach. Historical maps create a long record of spatial change, but with only a few temporal intervals. Satellite images, on the other hand, construct a scale with a short temporal record (30 years), but provide a high degree of precision within those confines, both temporally and spatially.

Introduction

Interactions in the coastal zone occur at a variety of scales, both temporal and spatial, creating challenging problems of data gathering and integration. The developing LOICZ database is designed to store data at a common spatial resolution (0.5 degrees). A common resolution enables the LOICZVIEW cluster package to analyze variables across different native scales.

Problems of scale

Historical maps provide data that has a long temporal range, but low spatial resolution. The maps below, compiled from various historical records (Cartographic Publishing House 1982), depict the advancement of the East Asian coastline from 200 BC (A.), 200 AD (B.) and 600-1200 AD (C.). Historical writings indicate that intensified farming of the loess plateau west of the Taihang Mountains during the Qin Dynasty (200 BC) dramatically increased erosion and thus the amount of sediment the Huang He (Yellow River) carried to the sea.

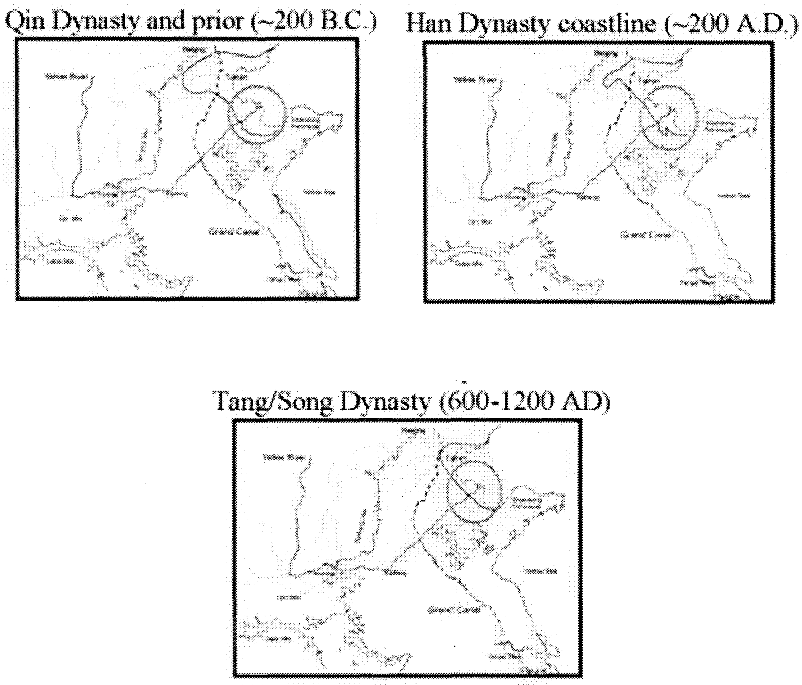

Figure 1. An example of historical maps.

Satellite imagery provides short term temporal, high resolution spatial data. These two Thematic Mapper images of the Huang He Delta (www.edcsns17.cr.usgs.gov/EarthExplorer/) depict signs of sediment being discharged into the Bay of Bohai. Coastline trends show that, despite flowing to the sea for less than four months of the year, the river continues to exhibit delta aggradation.

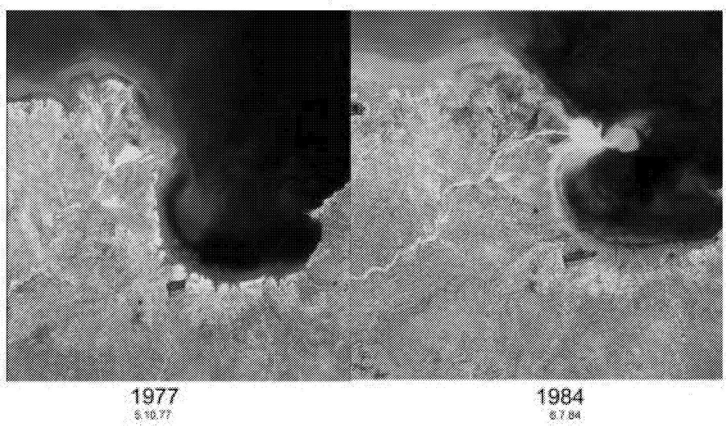

Figure 2. Thematic Mapper images of the Huang He delta.

Utilizing LOICZ and LOICZView

Land-Oceans Interactions in the Coastal Zone (LOICZ) seeks to describe phenomena impacting the transition between terrestrial and oceanic zones. These interactions occur at a variety of scales, both temporal and spatial, creating challenging problems of data gathering and integration. To address these difficulties, LOICZ is developing a database of environmental variables such as air temperature, ocean bathymetry, tidal range and river basin area. Based on a 30' grid cell, each variable is spatially assigned a cell classification as:

T Terrestrial land cells are typically defined as the cells containing only land (or fresh water).
C Coastal cells, defined as those containing a significant length of the World Vector Shoreline.
O1 Oceanic cells (I) are those extending seaward from the coastal cells the greater of (a) one degree, or (b) the 50 or 100m isobath in areas of a broad shelf, or (c) to include all of a budgeted area.
O2 Oceanic cells (II) are those additional cells needed to complete the infilling of relatively enclosed. water bodies or coastal seas.
O3 Oceanic cells (III) cover all remaining oceanic areas not included in the other classes.

To provide information beyond the limits imposed by the half-degree grid, the database includes sub-grid-scale parameterization, statistics on spatio-temporal variability, and alternative time slices. To analyze variables, similarity analysis using a cluster program (LOICZView), compares variables across scales.

Results

Classifying the coastal zone on the basis of runoff and basin area resulted in two critical observations:

1) The majority of the drained interior is affected by a few major stream systems which limit the places where continental runoff affects the coastline to a small number of points.
2) The coastal zone is impacted by a large number (4800) of small drainage basins.

Table 1. An example of cluster analysis results.

Cluster	**0**	**1**	**2**
Characteristics	Medium basin area	High basin area	Medium basin area
	Low runoff	Medium runoff	Medium runoff
Points/cluster	27	12	99
Basin area	1070010	2844980	294481
Basin runoff	87247.6	253078	225727.6
Cluster	3	4	
Characteristics	V. High basin area	Low basin area	
	High runoff	Low runoff	
Points/cluster	1	4868	
Basin area	5856890	9096.07	
Basin runoff	2122710	1766.45	

The cluster analysis identifies key locations for monitoring the impacts of change, both terrestrial and coastal. These locations indicate important areas where terrestrial basin typologies "meet" coastal typologies.

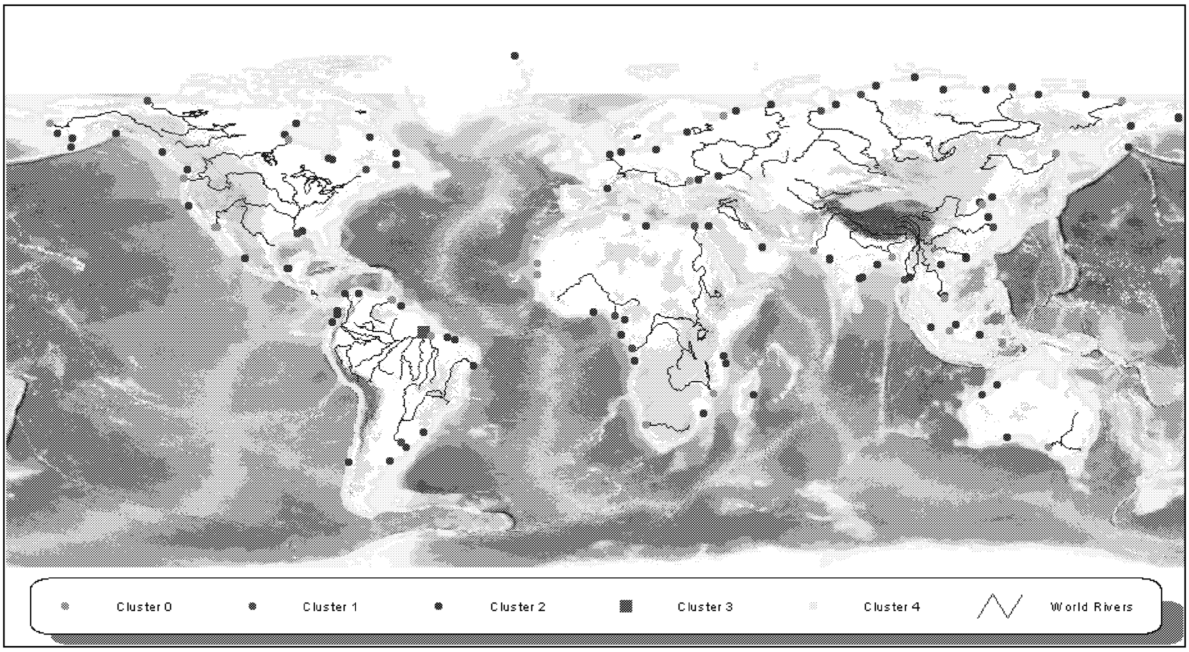

Figure 3. World Cluster analysis.

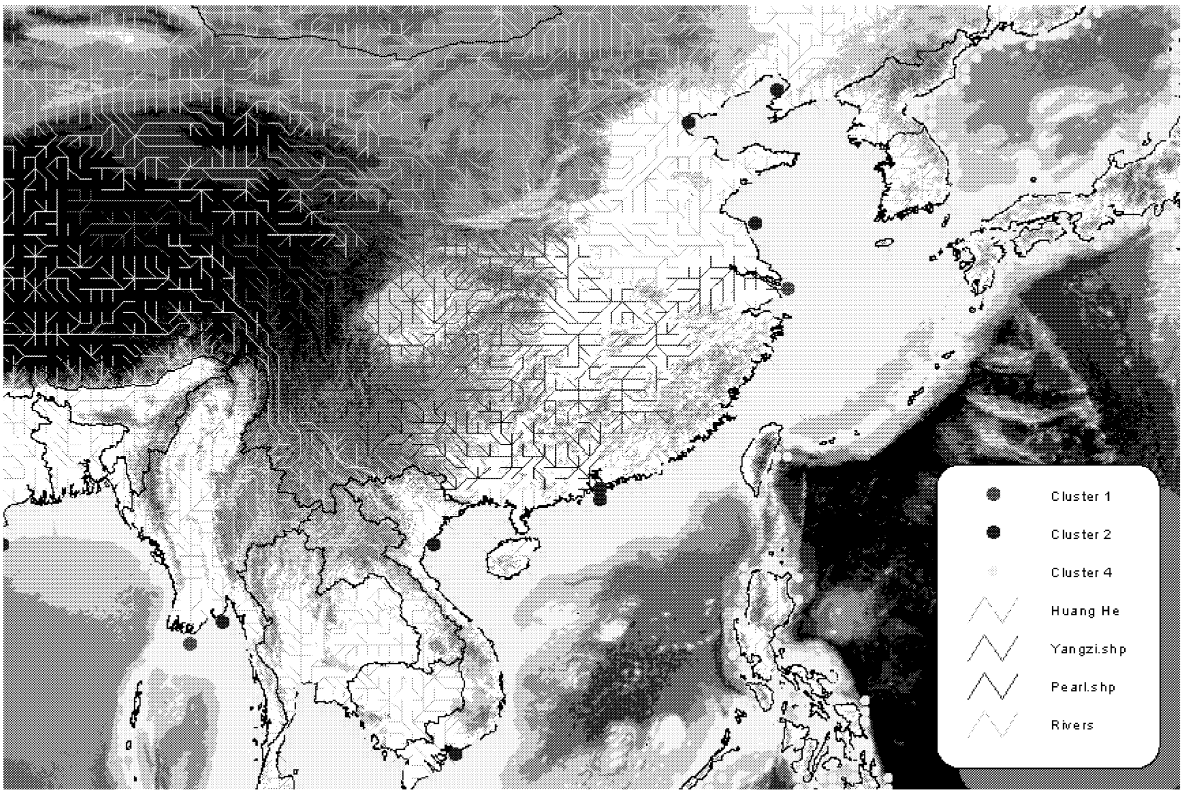

Figure 4. World Cluster analysis - East Asia

6. REGIONAL ASSESSMENT TABLES

Area 1. Vietnam and southern China. Coordinator: Josef Pacyna.

Table RA1.1 Major coastal impacts/issues and critical thresholds – Overview and qualitative ranking.

Coastal impact / issue	Local site/Region (contributing river basins)	Critical threshold (for system functioning)	Distance to Critical Threshold (qualitative or quantitative)	Impact category 1 -10	Reference / Data sources
HLM	Pearl River and small rivers Red River, Mekong River and small rivers	Destruction of mangrove (recent loss) HABs Change of ecological function Destroy of mangrove and coral reefs HABs recognized in Vietnamese rivers but few	Increasing HABs (especially in Mekong) Some data on mangrove and coral loss	HLM - 9	See synthesis tables in Chapter 2
ERO	Vietnam (local, low rivers such as Mekong and Red Rivers are having problems) China (not for the whole region)	River in low land is very dangerous The government does not have effective plans for controlling erosion. Human activities, natural processes and building dams and dykes	From 3620 km upper coastline, 469 km of coastline eroded, 100 km from PRD and adjacent areas eroded Red River has a total discharge of 114 mt/yr Dams in Vietnam trapped discharge of 48 mt/yr	ERO - 10	
FLO	Regional Mekong, Red and Pearl	Big flood in 1915 A medium flood in 1994 due to discharge from upper streams. HK had very big flood as well Floods occur almost every year in Vietnamese small rivers and in Mekong River Small flood in Red River. However, once there is a flood, it is very dangerous to low-lying areas due to dyke systems leaching to towns	Every year there is a flood Do not know what contributes to flooding The recurrent period of big floods is about 200 yrs Residents in south and center of Vietnam are suffering from floods Only small floods in north of Vietnam	FLO – 9	

Table RA 1.1 continued

SWI	More significant in major rivers, because of flat gradient (Red, Pearl, Mekong), regional not local	Three critical indicators of saltwater intrusion: 1. rice cultivation will be affected when exceeding 0.5 ppt 2. drinking water, saltwater intrusion, close to water supply, e.g. Macau salty drinking water, also in Vietnam 3. spawning of prawns and fishes will be affected		SWI - 7	
POL	Mekong, Red, Pearl	Oil pollution is typical in Mekong and Red (oil from petroleum industries and oil exploitation in offshore) Mekong and Red – PAHs, and pesticides Pearl, Hanjiang and Nandujiang were grossly polluted (oil, PAHs, pestcides)	Increased concentration of the pollutants In China 2 standards, 1 for fresh water, 1 for sea water, more than 30 parameters. Type I the best. Most fall in type II. Open sea always Type I. In term of POPs and heavy metal, can be reflected by uptake of contaminants in living organisms, e.g. oysters at western water of HK, human breast milk, DDT and HCH, 2 to 10 folds higher than European countries and Canada	POL – 8 regional problem	

Table RA 1.1 continued

BIO	Problems in all rivers (major and smalls) of the region	Caused by exploitation of living resources, habitat loss and different factors Threshold, indicator – mangrove, seagrass destruction, sedimentation. However, it is difficult to pinpoint the effects on food chain and food web	The no. of species decreased (birds, aquatic organisms) SE Asia project on seagrass study showed 10 to 20 species loss Destroy of wetland in HK due to urban expansion and land reclamation	BIO – 7	
HAB	Regional, coastal water	Very huge in China because a lot of fishes were kill (toxin from HABs). HABs appear and die suddenly which used up oxygen when decomposed by bacteria. Some algae also emit toxins. Worst case in China in 1998, also in HK and Mekong (not serious in Vietnam).	Fish kill is a good indicator. In the case of mariculture in HK, when there is fish kills caused by red tides, HK Government will verify and compensate the loss.	HAB – 9	

HLM - Habitat loss and/ or modification
ERO – Erosion
FLO – Flooding
SWI – Salt water intrusion
POL – Pollution
BIO – Biodiversity reduction
HAB – Harmful Algal Blooms

Area 1 Table RA1.2. DPSIR matrix characterizing major catchment based drivers/pressures and a qualitative ranking of related state changes impacting the coastal zone versus catchment size class.

State change dimension**:**

Major, medium, minor 0 = no impact ? = insufficient information

Time scale: p = progressive (continuous) d = direct (spontaneous)

Driver	Pressures	State change (qualitative index)			Impact on the coastal system	Time scale
		L	**M**	**S**		
Agriculture	• Nutrient runoff • Effluents • Pesticides • Increase of sediment transport • Agricultural wastes e.g. manure • Intensive agricultural activities along coastal areas • Reclaiming marginal land for agriculture • Loss of good agricultural land due to change of land use	major	major	major	POL Eutrophication ERO HLM HAB	p
Damming	• Nutrient and sediment sequestration • Change of hydrological cycles • Sediment budget alteration	major	major	medium	SWI ERO	d
Deforestation	• Siltation • Sediment and nutrient budget • Water shortage (water balance alteration) • Ecological disturbance	major	major	major	HLM ERO FLO SWI BIO	p
Urbanization	• Population growth, • Food and energy demand • Pollutant discharges	minor	minor	major	POL HLM	p
Industrialization	• Emission (pollution discharges, wastes) • Exploitation of natural resources	minor	minor	major	POL HLM	p

Table RA 1.2 continued

Aquaculture	• Globalization • Freshwater culture • Pollution sources from excess nutrients in mariculture cages • Disease	major in Vietnam, medium in China	medium	major	HLM BIO HAB	d (seasonal in China), P in Vietnam
Land Reclamation (coastal land)	• Sediment budget alteration • Change of hydrological cycle • Dredging in HK	minor	medium	medium	SWI	p
Sediment mining	• Sediment budget alteration • Sediment segregation, • Water level alteration	0	0	major	HLM BIO	p
Exploitation of living/mineral/ oil/ sand resources	• Rate of exploitation • Pollution discharge • Coastal erosion (small scale)	0	medium	major	HLM BIO	p
Lack of management	• Change of hydrological cycles • Rate of pollution discharge, • Balance of sediment • Increasing coastal use conflict	major	medium	minor	FLO ERO HLM SWI POL BIO	p / d

Table RA1.3/1.4/1.5 Area 1. The link between coastal issues/impacts and land based drivers – Overview and qualitative ranking on local or catchment /sub-regional or country scale.

Impacts	Drivers	Sub regions 1 - 10	Category	Trend	Reference *
HLM	Land reclamation	C P R V M	2 – 3 3 – 8 8 9 6	⇒	Papers, books,
	Aquaculture / Agriculture	C P R V M	4 9 9 10 9	⇑	
	Deforestation	C P R V M	2 2 4 8 4	⇓	
	Urbanization / industrialization	C P R V M	9 9 - 10 6 8 6	⇑	
ERO	Agriculture / auquculture	C P R V M	2 1 1 1 2	⇒	Database (global)
	Damming	C P R V M	8 2 10 7 5	⇑ ⇒ ⇒ ⇑ ⇒	

Table RA1.3/1.4/1.5 continued

	Deforestation	C P R V M	4 1 9 9 7	⇓	
	Land reclamation	C P R V M	3 2 9 5 4	⇒	Papers
	Sediment mining	C P R V M	9 2 2 5 1	⇒	
FLO	Deforestation	C P R V M	2 2 7 9 5	⇓	
	Land reclamation	C P R V M	7 8 7 2 7	⇑	
	Lack of management	C P R V M	8 8 8 8 8	⇒ ⇒ ⇓ ⇓ ⇓	National regulations
SWI	Agriculture	C P R V M	1 8 8 5 4	⇒	

Table RA1.3/1.4/1.5 continued

	Damming	C P R V M	1 – 2 4 8 7 5	⇒	
	Deforestation	C P R V M	2 2 4 5 2	⇓	
	Sediment mining	C P R V M	4 9 1 2 0	⇒	
POL	Agriculture / aquaculture	C P R V M	8 9 7 5 6	⇑	
	Urbanization / Industrialization	C P R V M	8 9 6 5 6	⇑	
	Exploitation of mineral resources	C P R V M	3 6 4 3 5	⇒	
BIO	Agriculture / aquaculture	C P R V M	5 6 6 4 6	⇑	

Table RA1.3/1.4/1.5 continued

	Damming	C P R V M	4 4 5 4 4	⇒	
	Deforestation	C P R V M	3 2 4 6 5	⇓	
	Urbanization / industrialization	C P R V M	7 9 6 5 6	⇑	
	Exploitation of mineral resources	C P R V M	2 2 8 6 7	⇑	
	Land reclamation	C P R V M	3 5 6 7 6	⇒	
HAB	Agriculture / aquaculture	C P R V M	3 9 1 1 2	⇑	
	Urbanization / industrialization	C P R V M	3 9 1 1 2	⇑	

Table RA1.3/1.4/1.5 continued

	Lack of management	C P R V M	2 8 9 8 9	⇑	Regulation enforcement

Sub-regions
C - Small rivers in South China (Hanjiang, Nandujiang)
P - Pearl River
R - Red River
V - Vietnamese small rivers (Bang-Ky Cung, Ma, Ca, Gianh-Tri-Huong, Thu Bon, Tra Khuc, Ba, Dong Nai)
M - Mekong River

1 = No impact 10 = Very serious impact
⇒ = stable I = increasing D = decreasing

Reference * = Further information from relevant workshop participants and references in chapter 2

Table RA6 Area 1 Scientific and/or Management Response to coastal impact/issues in East Asian Coastal Zones on catchment, sub regional and regional scale

River catchment	Response catchment scale		Response Sub regional / country scale		Response Regional scale	
River	Scientific	Management	Scientific	Management	Scientific	Management
Chinese River – Hanjiang, Nandujiang and small rivers	Monitoring programme e.g., in Zhongshan University, Institute of Hydrology which measures a number of variables, not necessarily extensive programmes. Some programmes managed by Guandong Environmental Protection Bureau, and also around HK water bodies by HKEPD.	Databases exist and are available. Legislations available on the catchment basis. Water quality standard for coastal area of HK.	Monitoring programme by Sea Management Agency. More than 10 stations. More monitoring in HK (joint monitoring by both HK and Guangdong governments more recently).	Less initiatives going on, e.g. Xiamen River.		
Pearl River	National level programme (863 project) monitor the whole PRD. SOA has a project with Japanese on S China Sea. HKBU together with Zhongshan University joint project on the uptake and bioaccumulation of heavy metals and PTS by fish (PCB, DDT).	PEIOS in 867 research project. National Programme and Integrated Observing System on Pearl River Estuary. 20 m of water depth coast managed by Pearl River Coastal Authorities and State Ocean Administration (SOA). River and sea levels below 20m water depth managed by Guangdong City Authorities and Pearl River Water Conservation Committee (PRWCC). Difficult to obtain data, validation and availability.			GEF/UNEP project study sources, fates and effects on 12 priority pollutants.	Fates of POPs.

Table RA1.6 continued

Red River	Few stations for monitoring. 1 to 2 stations for catchment studies. No system to monitor change from time to time.	Need monitoring programmes and regulations from authorities to review what is available.	Few stations for monitoring. 1 to 2 stations for catchment studies. No system to monitor change from time to time.	Need monitoring programmes and regulations from authorities to review what is available.		
Mekong R	Few stations for monitoring. 1 to 2 stations for catchment studies. No system to monitor change from time to time. Less than Red river scientific data.	Need monitoring programmes and regulations from authorities to review what is available	Few stations in South than in North.	Enforcement less effective from South to North.		
Vietnam small rivers	No continuous research Only measurement campaign Very few monitoring stations	No action at all Only regulations in respond to current / outbreak situation	No continuous research Only measurement campaign Very few monitoring stations	No action at all Only regulations in respond to current / outbreak situation		

Vietnamese Rivers – Bang-Ky Cung, Ma, Ca, Gianh-Tri-Huong, Thu Bon, Tra Khuc, Ba, Dong Nai

Area 1 Table RA1.7. Hot spots (point source) of land-based coastal impact and gaps in understanding as well as a first overview of issues to be addressed in future research (identifying the appropriate scale for the design of a new scientific effort).

River Catchment	Hot spot catchment scale		Hot spot Sub regional / Country scale		Hot spot Regional scale	
River	**Key issue, trend and gaps**	**Scientific approach**	**Key issue, trend and gaps**	**Scientific approach**	**Key issue, trend and gaps**	**Scientific approach**
Pearl	Lack of basic research. Research will support formulation of legislation. Poor enforcement of existing legislation. Sediment dredged from 8 outlets causing red tides.	Find methods to predict red tides and prevent damage in mariculture. Development of models to predict impacts. Analysis and action plan. Biotic model studies related to biomagnification in food web, e.g., use of biomarkers (fish, human breast milk) to study effects. However, no funding for further research work. Thus difficult to get to advanced stage.				
Red River	Low frequency of monitoring. Lack of common parameters/variables on measurement and analysis. Need a set of guidebooks to have common methods in collection of samples, analysis methodology so as to produce accurate results for all stations for comparison. Increase the capacity of training and human resources.	Examination of current status, there is already some studies undergoing Biogeochemical studies, erosion and flood scales, ecological, economic in terms of human dimension.	Same as catchment.	Fix the route of monitoring from Vietnam to China. Same as catchment.		

Table RA1.7 continued.

Mekong	No continuous set of data that based on measurement campaign types. Low frequency of monitoring. Lack of common parameters/variables on measurement and analysis. Need a set of guidebooks to have common methods in collection of samples, method of analysis so as to produce accurate results for all stations for comparison. Increase the capacity of training and human resources.	Some measures to control flooding and deforestation exist, but not so effective on enforcement from government. Set up monitoring network to control flood and erosion. Conflict between development and environment, stakeholder conflicts. Government focus on economy and food demand (should try to harmonize between environment conservation and economic growth/food demand).	Same as catchment.	Same as catchment .		
Vietnamese small rivers	Not much going on, not much information available. More emphasis should be placed on small rivers at national levels Physical, biological and chemical variables should be studied. Salt intrusion (related to domestic activities and agriculture).	Should bring to same level of study because of same level of interaction. To control flood and erosion (long-term approach).				

Vietnamese rivers – Bang-Ky Cung, Ma, Ca, Gianh-Tri-Huong, Thu Bon, Tra Khuc, Ba, Dong Nai

Area 2 East Asian Monsoon region. Coordinator: Chen-Tung Arthur Chen

Table RA2.1. Major coastal impacts/issues and critical thresholds – overview and qualitative ranking.

Impact code and relative class of importance e.g. 1- 10

Coastal Impact/Issue	Local site/Region (contributing river basins)	Critical Threshold (for system functioning)	Distance to Critical Threshold (qualitative or quantitative)	Impact category	References/ data source
Erosion (coastal geomorphology)	Yellow River Delta	about $0.35x10^9$ t/y of sediment into the sea through Lijin station	Zero	10	Yang
	Old-Yellow River Delta		Already some of tidal flat is lost	10	Saito/Yang
	Kaoping River (Taiwan)		Already causing collapse of a major bridge on the river and loss of beaches in Kaohsiung City	8	Chen
	Western Taiwan		1000 km² of coastal land is subsiding	8	Chen
	Japanese rivers		Already most of coasts are changed into artificial coasts	10	Saito
	Yangtze River	about $0.468x10^9$ t/y of sediment into the sea through Datong station	Has affected the formation of the Delta	8	Ren *et al.* 1994; Xi *et al.* 1994
			Wetland loss by reclamation		
	Liao River: area 281,300 km², length 1430 km. Including the Liao, Hun, Taizi, Dalin and Daqing river and so on; water volume inflowing into the sea 11.72 billion m³ in 1992.	Sediments through estuary to the sea($3.38x10^7$ t in 1992)		7	Xing
	Hai river: 2.6x105 km² basin area, including the North canal, Yongding, Daqing, Ziya rivers and South canal. The five rivers confluence into the Bohai Sea through Tianjin station. Length of Hai River 1090 km. Surface water 29.66 billion m³. Groundwater 28.45 billion m³. Annual precipitation 500-600 mm.	Annual runoff (15.4 billion m³). Sediments through the estuary into Bohai Sea ($6x10^6$ t). Annual sediments from Luan River into Bohai Sea ($2.67x10^7$ t)		3	Xing

Table RA2.1 continued

Eutrophication (habitat loss)	Western Taiwan		Most estuaries are already eutrophicated	8	Chen
	Eastern Taiwan		Isolated case of eutrophication	3	Chen
	Japanese coastal zone	violation of N, P, COD standard, occurrence of anoxia in estuaries	Not satisfied in a few enclosed bays	6	Watanabe
	Yangtze estuary	occurrence of dinoflagellate bloom	Increased nutrient loads are expected in the future and the system will be changed	9	Watanabe
		P 0.02, N 0.5	20%	9	Xing/Pu
	Liao River	N though the estuary into the sea (6.8x10^ t N y^{-1}); P through the estuary into the sea(1.73x10^4 t P y^{-1}) including the P(1.69x10^4 t P y^{-1}) together with sediments	Already	10	Xing
	Hai River		Most estuaries already eutrophicated	9	Xing
Damming	Yangtze		10 years until the effects of the Three Gorge Dam are felt	8	Chen
	Eastern Taiwan		Very far	1	Chen
	Western Taiwan		1000 km^2 of coastal land is subsiding and beaches are lost	6	Chen
	Yellow River	3.5 x 10^9 m^3/y of water	4.1 x 10^9 m^3/y of water	9	Yang
Freshwater discharge (diversion)	Yangtze	unknown	Increase in the next 20 years by the Three Gorges dam)	5	Casey
	Yellow River				
	small catchments (Taiwan)				
Chemical contamination	Eastern Taiwan		Slightly polluted	2	Chen
	Western Taiwan		Already heavily polluted	8	Chen
	Japanese coastal zone	violation of standard	No violation found	1	Watanabe

Table RA2.1 continued

	Yangtze	Hg 0.012, Cd 0.85		7	Xing 2000
	Liao River	metal concentration in river: Pb (17.7-53.4 mg/L); Cd (0.018-0.106 mg/L); Volatile phenol (0.33 mg/L); Petrolic materials (85.5-355 mg/L); Pesticide (0.04-0.125 mg/L).		7	Xing
	Hai River	Petroleum contamination	One of the most important chemical contaminant	6	Xing
	Eastern Taiwan		small effect	2	Chen
Agriculture	Werstern Taiwan		already causing eutrophication	7	Chen
	Yangtze	vast occupied small or part of lakes for farmland in the past decades	already causing pollution, flooding and eutrophication et al	5	Ren et al,1994
	Liao River	Already causing eutrophication		8	Xing
	East Taiwan		little effect	1	Chen
	West Taiwan		already cut by half because of contamination and overfishing	10	Chen
Fisheries	East China Sea		Not sustainable, may decline with further contamination, overfishing or reduction of freshwater outflow	8	Chen
	Liao River	Prawn cultivation zone reaches to 1300-1400 km; affects the sea about several thousands km^2, P overload in these areas		10	Xing
	Hai River		overfishing	10	Xing
	East Taiwan		not a problem	1	Chen
	West Taiwan		already caused human death occasionally	6	Chen
	Japanese coastal zone	occurrence of damage to aquaculture	still found but not big damage		Watanabe
Red tide	East China Sea	occurrence of damage to aquaculture	already caused human and fish death occasionally	2	public reports on newspaper
	Bohai Sea	damage to aquaculture		5	Yang
	Liao River		Often	6	Xing
	Hai River		Often	9	Xing

Table RA2.1 continued

Urbanization	East Taiwan		More people are moving in	5	Chen
	West Taiwan		most of the mangroves are gone and natural beaches replaced by concrete dykes	10	Chen
	Yangtze River Delta	occupied many lakes and coast zone	arable land decreased sharply et al which led to pollution, bio-diversity flooding and eutrophication	5	Ren et al ,1994
	Liao River	Movements of people from rural area to the cities and towns		6	Xing
Biodiversity loss	Yangtze River delta	no concrete data yet	may have influences in the near future	2	Xing/Pu
Sea-level rise (land subsidence)	Eastern Taiwan		not a problem in the foreseeable future	1	Chen
	Western Taiwan		1000 km^2 of coastal land is subsiding as a result of groundwater pumping	8	Chen
	Japanese islands		loss of most of sand beaches is expected within the next 100 years	4	Saito
	Yangtze		inundation of lowlands of the delta by storm surges & high tides in addition to the future sea-level rise is estimated. Subsidence in Shanghai by groundwater pumping.	4	Saito
	Hai River		Caused by groundwater overpumping	8	Xing
etc.	etc	etc			

References:

1) *Resource, Environment and Sustainable Development in Liao River delta* (in Chinese), edited by Zhang *et al.* 1997, Science Press, Beijing, pp13-93.
2) *Environment Evolution, Development and Protection in Beijing, Tianjing and Bohai sea region* (in Chinese).edited by G.J. Wan *et al.* 1987. Science Press, Beijing, pp15-121.
3) *Geology in Bohai Sea* (in Chinese). edited by Institute of Ocean, Chinese Academy of Sciences, 1985. Science Press, Beijing. pp7-21
4) *Oceanic Chemistry in Southeast Bohai Sea* (in Chinese) edited by Gu 1991, Science Press, Beijing, pp 5-430. Xing 2000, in press, *Biogeochemistry*.

Area 2 Table RA2.2. DPSIR matrix characterizing major catchment based drivers/pressures and a qualitative ranking of related state changes impacting the coastal zone versus catchment size class.

State change dimension: major; medium; minor; 0 = no impact; ? = insufficient information.

Time scale: p = progressive (continuous);d = direct (spontaneous).

Driver	Pressures	State change (qualitative index)				Impact on the coastal system	Time scale
		Large basins	**Medium basins**	**Small basins:** active coast	**Small basins:** passive coast		
Agriculture	Waste/nutrient	**medium**	**medium**	**major**	**major**	Contamination, eutrophication, flooding	**p**
	Incr.eased sediment transport;	**minor**	**medium**	**major**	**major**		**p/d**
Damming	Nutrient and sediment sequestration	**major**	**medium**	**medium**	**minor**	coastal erosion	**d**
(irrigation, human consumption,	Decrease of biodiversity	**Yangtze (3 Gorges dam)**	**medium**	**major**	**major**	estuary salinization	
sewage disposal,	Siltation	**minor**	**medium**	**major**	**major**	eutrophication	
industrial)	Contamination	**medium**	**medium**	**major**	**major**		
Damming	Changing hydrological cycle	**major**	**major**	**major**	**major**	Coastal erosion	**d**
	Sediment and nutrient sequestration	**major**	**major**	**major**	**major**	Nutrient depletion Degradation of ecosystem	**d**
	Increasing freshwater consumption	**medium**	**major**	**major**	**major**	Increase of natural hazards (storm surge, sea water intrusion)	**d**
						Loss of wetland and biodiversity Land sinking	**d**
De-forestation	Increasing frequencies of floods and droughts					Siltation	**P**
	Erosion	**minor**	**medium**	**major**	**major**		**P**
Navigation							
Urbanization (Point Source Effluents)	Contamination, eutrophication	**minor** **minor**	**medium** **medium**	**major** **major**	**major** **major**		**P** **p**
etc	**etc**					**etc**	

Table RA2.2 continued

Japanese Islands

Driver	**Pressures**	**State change (qualitative index)**				**Impact on the coastal system**	**Time scale**
		Large basins	Medium basins	Small basins: active coast	Small basins: passive coast		
Agriculture							
Domestic discharge	waste effluent (nutrients and chemical discharge)			**major**			**p**
Industrial discharge				**medium**			**p**

Area 2 Table RA2.3. The link between coastal issues/impacts and land based drivers – overview and qualitative ranking on local or catchment scale.

Category (1 low – 10 high) Trend categories: ⇑ = increasing, ⇒ = stable, ⇓ = decreasing

Coastal Impact/Issue	DRIVERS	Local catchment (allowing within and between catchment comparison)		Trend expectations	References/ Data sources
		Yellow River	Category		
Erosion	Damming	Yellow River 752 x 10^3 km^2 basin area run-off reduction by 78 % sediment reduction by 76 %	10 9 10	⇑ ⇑	Yang *et al.* (2001)
	Deforestation	Yellow River basin	8	⇒	
	sea-level rise	land subsidence due to tectonics and groundwater extraction is 10 mm/yr sea-level rise ~10 mm/yr	7	⇑	
	agriculture	Yellow River 85% consuming water for irrigation	9	⇒	Yang *et al.* (1998)
		Yangtze River			
Erosion	Damming agriculture	1.81 x 10^6 km2 basin, 9.79 x 10^11 m3yr-1 runoff the eroded area is about 6.9x10^5 km^2 the content of TN and TP are 1.6-2.2mg/l, 0.11-0.15mg/l which connected with fertilizer	10 10 10 10 8	⇑ ⇒	Xi *et al.* 1994 Duan 2000
	sea-level rise	May cause coastal erosion	4	⇒	
Eutrophication	urbanization	waste/nutrient	8	⇑	
	agriculture	fertilizer	8	⇑	
Contamination	agriculture	fertilizer	8	⇑	
	urbanization	waste	9	⇑	

Table RA2.3 continued

Biodiversity	damming		5	⇑	
	agriculture		4	⇑	
	urbanization		3	⇑	
Freshwater discharge (damming)	irrigation/diversion	area/volume combination runoff reduction type of agriculture agriculture intensity	10 4 5 10	⇑ (agriculture use + fluctuating runoff)	
	human consumption	population density	10	⇑	
	sewage discharge	population density animal type + densities	8 5	unknown	
	industrial	type density	5 5	⇑ (industrial use of freshwater)	
		Japanese Islands			
Eutrophication	agriculture domestic waste industrial waste		10 10 10	⇒ ⇒ ⇓	
Red tides	agriculture domestic waste industrial waste aquaculture		6 10 10 6	⇓ ⇓ ⇓ ⇓	
Contamination	domestic waste industrial waste Combination		6 10 8	⇒ ⇑ ⇓	

Table RA2.3 continued

		Liao River			
Erosion	Deforestation		6	⇒	Xing
	Agriculture		7	⇒	Xing
Eutrophication	Domestic Waste		8	⇑	Xing
Land subsiding	Agriculture		8	⇑	Xing
Contamination	Industry		8	⇑	Xing
Red tide	Domestic Waste		9	⇑	Xing
	Agriculture (fertilizers)		9	⇑	Xing
	Marine culture		10	⇑	Xing

		Hai River			
Eutrophication	Urbanization(domestic waste)		9	⇑	Xing
	Industry		10	⇑	Xing
	Agriculture		8	⇑	Xing
Land subsidence	Groundwater reserves ($2.845x10^{11}m^3$) Recovery ratio (91%) The annual maximum of land subsidence (89 mm y^{-1})		10	⇑	Xing

Area 2 Table RA2.4. The link between coastal issues/impacts and land based drivers – overview and qualitative ranking on local or sub-regional or country scale.

Category (1 low – 10 high), Trend categories: ⇑ = increasing, ⇒ = stable, ⇓ = decreasing

Coastal Impact/issues	DRIVERS	Sub-regional (i.e. by country or considering open versus enclosed seas)		Trend-expectation	References/ Data sources
		Japanese Islands	**Category**		
Eutrophication	agriculture		10	⇓	
	domestic waste		10	⇓	
	industrial waste		10	⇓	
Red Tide	agriculture		6	⇓	
	domestic waste		10	⇓	
	industrial waste		10	⇓	
	aquaculture		6	⇓	
contamination	domestic waste		6	⇒	
	industrial waste		10	⇑	
	combination		8	⇓	
	Mariculture	Local residual nutrient production	5		
	Municipal waste	Local urbanisation	10		

Table RA2.4 continued

		Yangtze River	Category (1 low – 10 high)		
Erosion	Damming	Yangtze River basin	9	⇒	Pu
		area	7		
		volume	8		
		runoff reduction	7		
	Deforestation	area	8	⇒	Pu
		residual TSS production	7		
	agriculture	fertilizer	9	⇑	Pu
	urbanization	waste	8	⇑	Pu
Eutrophication	agriculture	nutrients	9	⇑	
	urbanization	waste	8	⇑	
Contamination	agriculture	fertilizers	8	⇑	
		pesticide	9	⇑	
Biodiversity	damming		5		
	agriculture		4		
	urbanization		3		
Freshwater discharge/damming	irrigation/diversion	catchments			
	agriculture	decrease in run off			
	population growth			⇑	
	-sewage				
	-industry				
	water diversion to north	political			
	subsidence	groundwater pumping			
	wetland loss	Reclamation			

Table RA2.4 continued

		Taiwan			
Erosion	Damming	East Taiwan	2	slow ⇑	
		West Taiwan	8	slow ⇑	
	Deforestation	East Taiwan	2	⇒	
		West Taiwan	8	⇒	
	Diversion	East Taiwan	2	slow ⇑	
		West Taiwan	8	fast ⇑	
	Groundwater pumping	East Taiwan	2	slow ⇑	
		West Taiwan	10	stable	
Eutrophication	Aquaculture	East Taiwan	2	slow ⇑	
		West Taiwan	6	slow ⇑	
	Mariculture	East Taiwan	1	⇒	
		West Taiwan	5	slow ⇑	
	Municipal	East Taiwan	2	slow ⇑	
		West Taiwan	9	⇒	
	Industrial	East Taiwan	2	slow ⇓	
		West Taiwan	8	slow ⇑	
Damming					

Table RA2.4 continued

		Liao River	)		
Eutrophication	Domestic waste		9	⇑	Xing
	Fertilizers		9	⇑	Xing
	Industry		9	⇑	Xing
Red tide	Marine culture		10	⇑	Xing
	Domestic waste		9	⇑	Xing
	Fertilizers		9	⇑	Xing
	Industry		8		
Contamination	Industry		8	⇑	Xing
	Marine culture		10	⇑	Xing

		Hai River	Category(1 low – 10 high)		
Eutrophication	Domestic waste		9	⇑	Xing
	Industry		10	⇑	Xing
	Agriculture		8	⇑	Xing
Red tide	Marine culture		10	⇑	Xing
	agriculture		8	⇑	Xing
	Industry		10	⇑	Xing
Petroleum contaminant	Exploit petroleum on land and in Bohai Sea		8	⇑	Xing

Area 2 Table RA2.6. Scientific and/or Management RESPONSE to coastal impact/issues on catchment, sub-regional and regional scale.

River catchment	RESPONSE Catchment scale		RESPONSE Sub-regional/ Country scale		RESPONSE Regional scale	
	Scientific	**Management**	**Scientific**	**Management**	**Scientific**	**Management**
Japan – all rivers		Legislation: environmental standards are set in the river		Legislation: environmental standards are set for COD, N, P concentration and total of COD, N, P load to the bays and coastal seas are set.		
Yellow River	Erosion-accumulation hazards project from 1995-2000, funded by MOST of China Evolution of the Huanghe delta project funded by NSFC, 2000-2002 Program on erosion to be reviewed in 2001	*Commission on coast protection from erosion was established by the Shenli Oil Administration, 2001 *"Blue Sea" action program for protection the Bohai Sea from pollution is underway by the National Bureau of Environmental Protection of China *Action to prevent flow-cut-off of the Huanghe was taken in 1998				
Yangtze River	*Monitoring of water quality (1999); * "The environmental change of water and land resources in the yangtze River delta " funded by NSFC, 1999-2001; *. "balance of the arable land changes and its sustainable development" funded by the Ministry of Land and resources (1999-2001) *Database set up *several universities and institutes have already undertaken research on various aspects of the river	* Changjiang River Commission was established many years ago and has accumulated aboundent data, especially about middle-upper reach river basin. *Legislation in place government *RS and GIS *Monitoring station established				

Table RA2.6 continued

Liao River	From 1987 to 1994, the influence of human activities on environments has been systematically studied in Liao River valley, particularly in the delta areas.	The prawn culture areas should be strictly controlled in the East Liao estuary.				
Hai River	The interactions between human activities and Environment, have been systematically studied in 1980s and 1990s.	From 2001, water will be transferred from the South (Changjiang River) to the North (Hai River). The government will make the water resource commercialized to effectively utilize the water, control the water pollution, restrict waste water discharge by laws.				

Area 2 Table RA2.7. Hot spots of land based coastal impact and gaps in understanding as well as a first overview of issues to be addressed in future research (identifying the appropriate scale for the design of a new scientific effort).

River Catchment	Hot spot Catchment scale		Hot spot Sub regional/ Country scale		Hot spot Regional scale	
	Key issue, trend and gaps	**Scientific approach**	**Key issue, trend and gaps**	**Scientific approach**	**Key issue, trend and gaps**	**Scientific approach**
Yangtze	*land use change and its drivers analysis *soil erosion and land degradation research (including budget of flow of N, P, S etc) *contamination *biodiversity *sources of surface contamination	Biogeochemical studies, Residual calculation by economic sectors Critical flux investigation Stakeholder and scale analysis	*land use change and its drivers analysis	It is important to identify the process of land use changes (quantity and quality) its spatial and temporal pattern. How are human dimensions effect on and what are the consequences?	…	…
	*dam	Biogeochemical studies				Strong interaction exists between the Changjiang catchment and the East China Sea. It is important to know what kinds of changes will be created in water cycle and biogeochemical cycle in the Changjiang catchment by damming and great western development. It is important to know that what kind of response in the ecosystem function can be anticipated in the East China Sea.

Table RA2.7 continued

	*Sediment and nutrient flux charges	Modelling the ecosystem functions in the basin				
	*Freshwater discharge change *Great Western Development. *Coastal erosion after 3 Gorges project and water regulating project	*Establishment of process and systematic models for evolution and prediction of the land use change. *Assessment of resources and environment changes including cost-benefit analysis. *Prediction of coastal erosion				
Yellow River	*Sharp reduction of water and sediment into the sea, trend will continue	*Systematic investigation of the coast erosion and consequences in relating to the changes. * Flux threshold on sediment, C, N, P, Si. *Monitoring system of the coast changes. *Processes and systematic modelling of the coast changes. *Assessment of resources and environment caused by the changes, and their socio-economic impacts. *Regulating water and sediment resoiurces through the whole Yellow River catchment.				
	*Intensive coast erosion increasing continue					
	*Strong damming effect of large reservoirs					
	*Increasing water consumption					

Table RA2.7 continued

	*Delta subsidence, storm surge and saltwater intrusion					
	*Wetland loss					
	*No quantitative data of the delta erosion and subsidence.					
	*No assessment of the damage by the erosion.					
	*No assessment and prediction of the coast change after the Xiaolangdi reservoir.					
	*No assessment of the reduction of the water and sediment on the ecology and environments in the coastal zone.					
	*No fluxes of C, N, P, Si from land into the sea					

Table RA2.7 continued

Liao River	Effect of Resource development on environment, particularly petroleum and natural gas exploitation. Rational utilization of water resource	Biogeochemical studies; the extension of the water-saving techniques in industry and agriculture.				
Hai River	Water shortage in urban areas Overpumping of groundwater	Biogechemical approaches; water balance research and the extension of the water-saving techniques.				

Table RA2.7 continued

Japanese sub-region						

Key issue

Land is very limited in Japan and the economical development inevitably put a strong pressure to utilize the coastal zone for economical purpose. As a result, most of the natural coastal lines in the bays were lost by constructions of harbours, factories, airports etc. Recently the land-fit for solid waste disposal becomes an important issue. Environmental assessment has been strongly enforced to the coastal zone and conservation of natural coastal zone and wetland are the important issues. Many kinds of chemicals will be discharged into the sea through the rivers, atmosphere and cross boundaries. The consumption of fish is very high in Japan and the fates of these chemicals through the food-chain and ecoaccumulation are in great concern in Japan.

Scientific approach

We introduced the environmental standard of COD, N, P concentrations to the coastal zone and set the global on the reduction of total amount of pollution load (COD, P, N) to the coastal sea. In Tokyo Bay, it was estimated that about 50% of reduction in total amount of pollution load to Tokyo Bay was necessary to satisfy the environmental standard in entire Tokyo Bay. In particular the reduction of the pollution load from non-point source is essential.

Taiwan sub-region						

Key issue/trend/gaps

Severe water pollution, wetland erosion, land subsidence, chemicals, water shortage, diminished fish catch

Scientific approach

Linking problem to economic losses and health hazards in order to convince policy makers and the public that the economic growth must be in line with the health of the environmental; how the reduced freshwater discharge affects the shelves must be determined.

Area 3 Cold temperate and arctic regions. Coordinator: Horst Behrendt

Table RA3.1. Major coastal impacts/issues and critical thresholds – overview and qualitative ranking.

Coastal impact/issue	Contributing river basins	Critical threshold	Distance to critical threshold	Impact category	References/ data source*
	Bering Sea				
Contamination (heavy metals)	Local, along the coastline	Habitat loss Contamination of species	Large (regionally), but small locally	1	1997-1998 papers and reports
Oil exploitation	Anadir	Habitat loss	Large at present, decreasing trend	1	
Over-grazing (Agriculture)	Anadir	Increasing sediment transport	Large	2-3	
Deforestation	Kamchatka Peninsula	Increasing sediment transport	Large	4-5	
	Okhotsk Sea				
Contamination (heavy metals)	Small rivers	Habitat loss Contamination of species	Large	1	
Oil exploitation		Habitat loss	Large	1	
Floods	Amur	Increasing sediment transport, Water level		2-3	
Contamination (organic matters)	Amur	Habitat loss	Large	2	
Deforestation	Small rivers, Amur	Increasing sediment transport	Large	2-3	
	Japan Sea				
Contamination (heavy metals)	Small rivers	Habitat loss Contamination of species	Large	1	
Oil pollution (caused by transport)	Sakhalin Island	Habitat loss	Large	1	
Floods	Razdolnaya,Rudnaya, other small rivers	Increasing sediment transport, Water level	Large	2-3	
Contamination (organic matters)	Tumen, Amur Bay, Peter the Great Bay	Habitat loss	Large, intermediate	2-3	
Deforestation	Razdolnaya, Tumen, Partizanskaya other small rivers	Increasing sediment transport, Erosion	Large	2-3	
Eutrophication	Eastern Korean coast, up to Tumen River estuary	Habitat loss Red tide	Large	1-2	

References * = - further information from respective group participants

Area 3 Table RA3.2. DPSIR matrix characterizing major catchment based drivers/pressures and a qualitative ranking of related state changes impacting the coastal zone versus catchment size-class.

Region	Driver	Pressures	Large basins	Medium basins	Small basins	Impact	Time Scale
	Northern						
	Agriculture	Over-grazing Sediment transport		minor	minor	Contamination	d
	Deforestation	Sediment transport		minor-medium	minor-medium	Erosion	p
	Mining	Sediment transport	minor-medium	minor-medium	minor-medium	Contamination	p
	Navigation		medium	0	0		
	Urbanization	Waste effluent		0-minor	0-minor	Contamination	p
	Southern						
	Agriculture		medium	major	minor-major	Eutrophication	
	Damming		minor	0	medium		p
	Deforestation		medium	medium	0-major	Erosion	p
	Mining					Contamination	p
	Navigation						p
	Oil (Amur)		minor-medium	0	0-medium	Contamination	p
	Urbanization		medium	minor	0-medium	Contamination	p

Area 3 Table RA3.3. The link between coastal issues/impacts and land-based drivers – overview and qualitative ranking on local or catchment scale.

Trend expectations: ⇑ = increasing, ⇒ = stable, ⇓ = decreasing

Coastal Impact/issues	Drivers	River	Category	Trend expectation	References/ data sources
		Amur / small rivers			
Contamination	Mining		2	⇒	
	Deforestation		3	⇑	
	Urbanization		2-3	⇑	
	Agriculture		3	⇑	
		Tumen and Korean/Japanese rivers			
Eutrophication	Agriculture		1	⇑	
	Urbanization		1	⇑	
		Anadir			
Contamination	Mining		1	⇑	
	Agriculture		1	⇑	

Area 3 Table RA3.4. The link between coastal issues/impacts and land based drivers – overview and qualitative ranking on local or sub-regional or country scale.

Coastal Impact/issues	Drivers	Sub-region/ River	Category	Trend expectation	References/ data sources
		Bering Sea			
Over-grazing	Agriculture		2	⇑	
Floods	Deforestation		2	⇑	
Erosion	Deforestation		2	⇑	
Contamination	Mining		2	⇑	
	Agriculture		1	⇒	
		Okhotsk Sea			
Contamination	Agriculture		2	⇑	
	Mining		2	⇒	
Floods	Deforestation		3	⇑	
Input of Organic matter	Urbanization		1-2	⇑	
		Japan Sea			
Eutrophication	Agriculture		2(local)	⇑	
Contamination P Detergent	Agriculture			⇑	
	Deforestation		3-4	⇒	
	Mining		3-4	⇒	

Area 3 Table RA3.5. The link between coastal issues/impacts and land-based drivers – overview and qualitative ranking on regional scale.

Coastal Impact/issues	Drivers	Full-Region (B+O+J)	Category	Trend expectation	References/ data sources
Contamination	Agriculture		2	⇑	
	Deforestation		1	⇑	
	Mining		3-4	⇑	
Floods	Deforestation		3	⇑	
	Urbanization		2	⇑	
Eutrophication	Agriculture		2 (Local)	⇑	
Over-grazing	Agriculture		2	⇒	

Area 3 Table RA3.6. Scientific and/or Management RESPONSE to coastal impact/issues on catchment, sub-regional and regional scale.

River catchment	Response Catchment scale		Response Sub-regional scale		Response Regional scale	
	Scientific	Management	Scientific	Management	Scientific	Management
Amur River	Monitoring and measurements (since 1960 for 3-5 parameters, basic stations 21 parameters and 5 special stations 50 at present), but not in a systematic way	Separate management plans by Russia and China, but no joint programs for the whole system International commission started to work in 1998				
Tumen River	1 station in Russia, 1 in North Korea (now closed), around 5 in China	No coordination between the countries.		Tumen River development scheme discussed by the countries involved		

Area 3 Table RA3.7. Hot spots of land based coastal impact and gaps in understanding as well as a first overview of issues to be addressed in future research (identifying the appropriate scale for the design of future scientific efforts).

River catchment	Hot spot Catchment scale		Hot spot Sub-regional scale		Hot spot Regional scale	
	Scientific	Management	Scientific	Management	Scientific	Management
Amur River (urban areas Amursky, Harbin, Khanka), Tumen rivers	Knowledge transfer from natural science to social science	International commission for the protection of Amur Monitoring stations	Method and standard of monitoring, complex analysis of sources and transport of materials within the river system Knowledge transfer from natural science to social science		Nutrient and sediment budget for individual seas	Data availability International collaboration

"Northern Group" discussion – report on the coastal zone of the three marginal seas:
Table 1. Bering Sea – There is some chemical pollution in response to oil and gas mining (drilling platforms), but it is minor (localized effects). Anadir River and Anadir Gulf are affected. Some papers about geochemistry have been published in 1997 (in Russian language). Floods, agriculture and fishery also affect slightly the coastal zone. Statistical data are available from Russia. Transport of sediment into the coastal zone and coastal erosion is starting to increase. In the future, these can be intensified, and the development will be extended to the southern part. On the Kamchatka Peninsula mining (for gold) and deforestation cause sediment pollution, and change the sediment transport and coastal erosion patterns. Institute of Natural Resources and Environmental Problems has data sets for this area. Okhotsk Sea – In the northern part, there are only a few settlements. The human effect on the coastal zone is insignificant. But, to the south, some significant effect is associated with the Amur River. Around 96% of the river discharge is directed to the Okhotsk Sea and 4 % goes to the Sea of Japan. On land mining for gold and on the shelf oil/gas mining (on and near the Sakhalin Island, which is separated from the mainland by a strait 3 km in width) are intensive. Floods occur every year. Oil pollution takes place on the shelf. Chemical pollution (pesticides, heavy minerals, etc.) also occurs. The plume move of the Amur River varies, in response to weather conditions. Eutrophication is minor. The Sea of Japan – To the north of Peter the Great Bay, localized intensive contamination of sediment due to mining takes place. From Peter the Great Bay to the Russia/Korea border, chemical pollution in sediment by hydrocarbon and river discharge (heavy metal) occurs in coastal embayments. Pollution is also associated with Tumen River (organic pollution of the sediment rather than heavy metal from China side and mining from North Korea in summer times). At the estuary, eutrophication and red tides take place. Nuclear waste dumping may become a problem in the future. Along the Korean coastline, there are no large rivers. Eutrophication is a major problem; the ocean currents are directed towards the north from the south, which causes accumulation of nutrients and red tides in later summer. Coastal erosion may be a secondary problem. Along the Japanese coastline, there are some relatively large rivers with sediment and nutrient input. However, there is a lack of information. In general, mining is a dominant activity which affects the coastal zone.

Table 2. Northern part: Agriculture - over-grazing leads to coastal erosion and sediment transport; contamination; direct influences. Mining – sediment transport, progressive influences. Deforestation – sediment transport, micro-benthos, progressive. Urbanization – minor change, progressive. Southern part: Agriculture – water-nutrient effluent, sediment transport; eutrophication, with progressive and direct influences. Damming – minor change to no impact, progressive. Deforestation – sediment transport, erosion and siltation; progressive. Navigation - Urbanization – waste effluent, input of organic water, medium to minor change, progressive. Oil production for the Amur River basin – some impacts.

APPENDICES

Appendix I Human dimensions of land-based fluxes to the coastal zone: the LOICZ-Basins approach

by H.H. Kremer, Wim Salomons and C.J. Crossland

This appendix provides an introduction in methodology of the regional assessment and synthesis of human dimensions of land-based fluxes to the coastal zone as performed in the LOICZ-Basins core project. In using a common methodology, harmonized assessment protocols and project designs for research on global scales, the LOICZ-Basins framework aims to assist in interregional exchange and acquisition of funding opportunities on local, sub-regional and regional scales.

Background

Coasts worldwide are subject to many pressures which are expected to continue or increase in the future. Natural flows of water, nutrients and sediments to the coast are largely and increasingly influenced by past and planned physical changes in rivers (e.g., damming). In addition, the increase in tourism, fisheries, urbanization and traffic will offer challenges for the coastal zone managers and regulators. The management issues and their solutions require an integrated approach of the natural and socio-economic sciences (Turner *et al.* 1998; Salomons *et al.* 1999). Numerous studies (often mono-disciplinary) have been conducted to deal directly with these issues but could benefit from more integrated assessment. This integration of the results of past studies requires a simple and harmonized framework for assessment and analysis. For the integration LOICZ-Basins uses the DPSIR framework:

LOICZ-Basins faces three major challenges:

1) to determine the time delay between changes in land-based material flows (due to socio-economic activities, morphological changes or regulatory measures) and their impact on the coastal zone system.
2) to generate an improved understanding of the complexities of the coastal sea environments and to derive from this complex environment the "critical loads".
3) to consider the multiplicity of interests and stakeholders affected by transboundary issues, particularly when local, regional, national, and multi-national governmental bodies with conflicting interests are involved.

The DPSIR framework

The Driver-Pressure-State-Impact-Response or DPSIR scheme (Turner *et al.* 1998; Turner and Bower 1999) provides a standardised framework for site assessment and evaluation. It enables the calculation and modelling of the impacts of change on the delivery and use of environmental goods and services expressed in scientific and monetary terms. The scheme sets up a platform for independent review and evaluation of political and managerial response and options. The elements of this framework are:

Drivers: resulting from societal demands, sectoral activities with consequences for the coastal zone include:
- urbanisation
- aquaculture
- fisheries
- oil production and processing
- mining
- agriculture and forestry
- industrial development
- land use change.

Pressures: processes affecting key ecosystem and social system functioning (i.e., natural and anthropogenic forcing affecting and changing the state of the coastal environment):

- damming and other constructions
- river diversion, irrigation and water abstraction
- industrial effluents (industrialisation), agricultural and domestic wastes (urbanisation)
- navigation and dredging
- sea-level rise induced by land-based activities and affecting the coastal zone (e.g., decrease of riverine sediment load leading to instability of coastal geomorphology)
- other forcing functions (not primarily anthropogenic) such as climate change.

State and State change: the indicator functions and how they are affected:

- water, nutrient and sediment transport (including contaminants where appropriate) observed in the coastal zone as key indicators for trans-boundary pressures within the water pathway. Indicators are designed to give an overview of the environmental status and its development over time and to enable derivation of critical load information
- geomorphologic settings, erosion, sequestration of sediments, siltation and sedimentation
- economic fluxes relating to changes in resource flows from coastal systems, their value and changes in economic activity including the valuation of natural resources, goods and services.

Impact: effects on system characteristics and provision of goods and services:

- habitat alteration
- changes in biodiversity
- social and economic functions
- resource and services availability, use and sustainability
- depreciation of the natural capital.

Response: action taken on political and/or management level:

- scientific response (research efforts, monitoring programs)
- policy and/or management response to either protect against changes such as increased nutrient or contaminant input, secondary sea level rise, or to ameliorate and/or rehabilitate adverse effects and ensure or re-establish the chance for sustainable use of the system's resources.

The pressures are manifold, so we narrow them down within the LOICZ context, which deals with changes in biogeochemical cycles as major indicators. The LOICZ-Basins project therefore deals with the impact of human society on the material transport such as water, sediments, nutrients, heavy metals and man-made chemicals to the coast. It assesses the loads and their coastal impact and tries to provide feasible management options together with an analysis of success and failure of past regulatory measures. Since changes in fluxes are mostly land or catchment-based, the catchment–coastal sea system is treated as one unit – a water continuum. In applying this scale to loads and coastal change phenomena this means that beyond activities from agriculture, fisheries, urban development, industry, transport, tourism also morphological changes made to a catchment (e.g. damming) have to be taken into account.

In particular the following parameters will be assessed:

- material flow of water, sediments, nutrients and priority substances (past, current and future trends);
- socio-economic drivers which have changed or will change the material flows;
- indicators for impacts on coastal zone functioning; and to derive from them
- a "critical load" for the coastal zone and "critical thresholds" for system functioning.

Linking coastal response to socio-economic drivers

This critical load and threshold concept being developed within the UN/ECE CLRTAP convention will develop this link. The United Nations Economic Commission for Europe's convention on Long-Range

Transboundary Air Pollution has held several workshops and produced handbooks on the critical load concept for terrestrial and freshwater systems. In LOICZ-Basins these concepts are extended to the marine environment. In a systems approach it can be used (as has been done for atmospheric pollution abatement) for a cost-benefit analysis of management options. Scenario-building is an integral part of this analysis. Critical loads provide key information for the development and application of indicators for monitoring purposes as required, for example for the implementation of the Coastal Global Observation System, C-GOOS, of UNESCO's IOC.

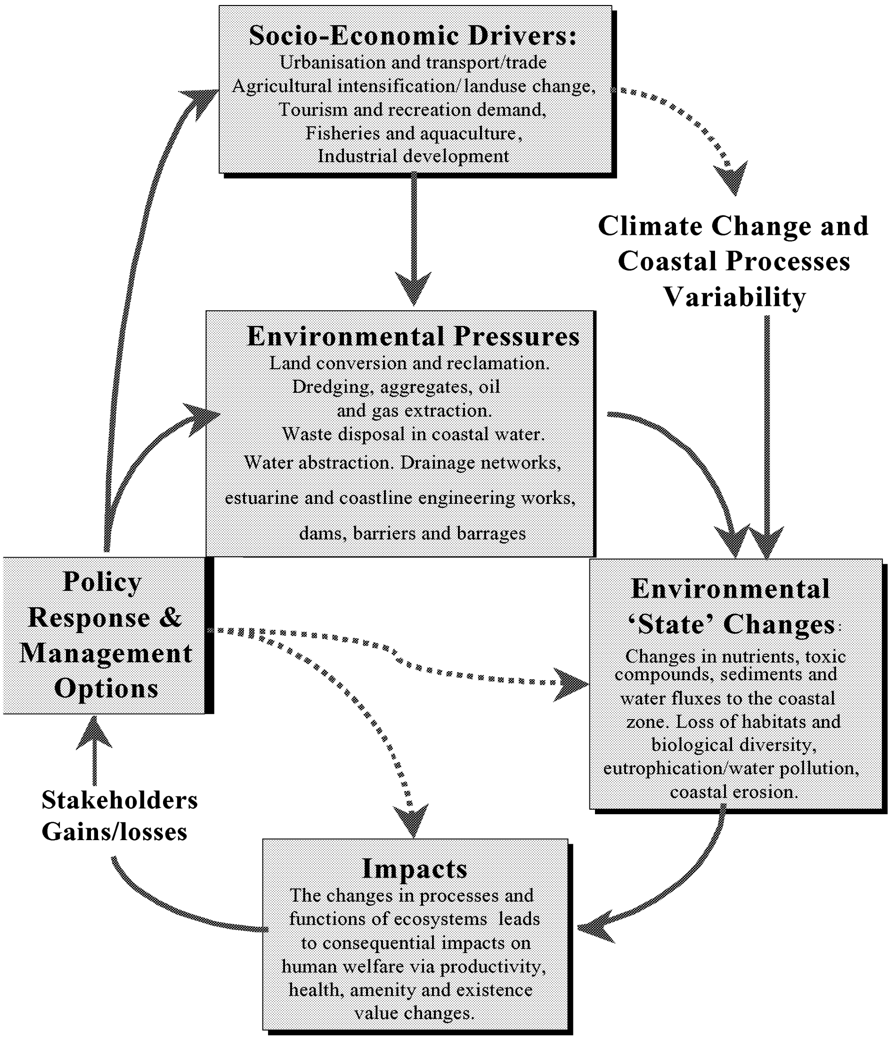

Figure A1.1. Description of the Driver-Pressure-State-Impact-Response

LOICZ-Basins employs different approaches to identify **targets and indicators** for the coastal response:

- The simple "policy-oriented" approach takes the critical loads agreed upon in international treaties (e.g., the 50% reduction scenario within the Rhine Action Plan, also adopted for the North Sea).
- The "ecosystem" approach uses historical data on the response of the coastal system to changing loads and identifies indicators. This approach will attempt to discriminate between natural states and anthropogenically altered states.
- The "regional management" approach is based on consultation with local authorities and identifies their criteria for indicators or critical loads. This incorporates other indicators than those based on scientific arguments alone.

The indicators and targets are used to derive critical concentrations. Taking into account transformations and dispersion in the coastal environment, a critical load to the coastal zone can be calculated. This critical load, the **critical outflow** of the catchment, is a combination of inputs by socio-economic activities and transformations in the catchment and its delta/estuary. Once these links and the transformations of the loads have been established it will be possible to carry out scenarios for cost-benefit analysis and trade-offs. This will require the integration of existing modelling tools from the natural and social sciences.

The DPSIR framework is applied to determine critical loads of selected substances under various development scenarios with diverse biophysical and socio-economic settings, triggering discharges into the coastal seas. It provides an interdisciplinary platform for joint approaches of natural, social and economic scientists, and to incorporate stakeholders - industry, agriculture, environmental organizations and citizens.

Large catchments seem to be obvious examples to be addressed within a global LOICZ synthesizing effort (e.g., Amazon, Nile, Yangtze, Yellow, Orinoco), and East Asia is dominated by big streams. However, from the perspective of coastal change on regional and global scales, considerable if not major influence from land-based flows is generated in small to medium catchments with high levels of socio-economic activity. Changes in land cover and sectoral use need much shorter time-frames to translate into coastal change and usually exhibit more visible impacts in smaller catchments than in large catchments where the "buffer capacity" against land-based change is higher simply as a function of catchment size. Thus, small and medium catchments are in principle of equal priority to the global LOICZ-Basins assessment. They dominate the global coastal zone (in Vietnam, for example, they characterize extensive parts of monsoon-driven runoff to the South China Sea). In island-dominated regions such as the South Pacific or the Caribbean – or in East Asia the island of Taiwan and the Japanese Archipelago - frequently whole islands can be considered as one catchment affecting the coastal zone and influences are generated by both anthropogenic drivers and global forcing.

The approach

Regional networks, assessment workshops/desk studies

Through two-stage regional workshops, LOICZ-Basins builds up regional multidisciplinary networks of scientists who bring their experience and existing information into the synthesis process. The first workshop identifies the pertinent regional issues and provides a first ranking order of current and predicted impacts with trend analysis, based on expert judgement and published scientific information. A second workshop finalizes the regional synthesis, improves the geographical and thematic coverage and assists in preparing research proposals for local and regional funding. Emphasis is given to close coupling of biogeochemical and physical sciences with human dimensions. Workshops have been held and networks established in Europe, Latin America, East Asia (this report) and Africa, while desk studies cover the Caribbean, Oceania and the Russian Arctic. (The East Asia Basins assessment was run as a single workshop. This was possible through the broad scientific and geographical coverage provided by the network. However, the two-step approach is preferable).

In February 2001 the European Catchments (EuroCat) project, funded by the European Union, started (http://www.iia-cnr.unical.it/ EUROCAT/project.htm) as a direct result of a LOICZ assessment. The EuroCat design, objectives and modelling approaches serve as templates for the development of other regional catchment-coastal zone projects currently being developed for Africa (in implementation with support from START as a pilot study phase 2002/03 – four catchments), and Latin America. In East Asia a similar development is foreseen for the near future.

A **LOICZ-Basins** web-page is now available at the GKSS Research Center, Geesthacht, Germany, (http://w3g.gkss.de/projects/loicz_basins/) and through the LOICZ web-site (www.nioz.nl/loicz/). It is updated continuously and provides pdf copies of reports.

Proposals and projects that develop from regional LOICZ-Basins efforts contribute to the global LOICZ assessment. They also contribute to the Integrated Coastal Area Management initiative, ICAM, as well as to the Coastal GOOS "Global Ocean Observing System" of UNESCO/IOC. Links to the typology up-scaling effort considering global river run off and coastal biogeochemistry (a joint project of LOICZ and BAHC through the University of New Hampshire, are being pursued (http://www.kgs.ukans.edu/Hexacoral/Tools/tools.htm). Watching briefs exist with other global efforts such as GIWA, the WWAP and Millennium Assessment. Increasing the links with the Regional Seas initiatives under UNEP and the GPA is under consideration.

The framework for LOICZ-Basins synthesis and project development

Since LOICZ-Basins workshops have a regional focus, assessment and ranking follow a hierarchy of scales finally allowing a full regional picture to be generated. The scales increase from:

- local catchments via
- sub-regional or provincial scales up to
- regional scale which could be a country (e.g., continental China) or a sub-continent or continent.

To facilitate thinking and to guide the evaluation of existing information, the Driver-Pressure-State-Impact-Response scheme (DPSIR) has proven to be an appropriate descriptive framework. The steps taken are:

a) set up a **list of coastal change issues** of and **related Drivers** in the catchment (plenary-task).
b) characterize and rank the various issues of change based on either **qualitative information** (i.e., expert judgement - if there are no hard figures) or **hard data** coming from investigations or archived material; this includes identifying **critical load** and **threshold** information for system functioning.
c) derive a list of current or prospective **"hot spots"** representative of a type or class of catchment-coast system, from which to develop a **proposal** for future interdisciplinary work.

LOICZ-Basins aims to provide an **expert typology** of the current state and expected trends of coastal change under land-based human forcing and natural influences. The assessment follows a set of key questions which cover the various aspects and scales of the DPSIR analysis and follow a sequence of **assessment tables**, participants are asked to fill in prior to the workshops. A generic scheme is shown below. All major assessment tables closely follow this scheme, and allow intra- and inter-regional comparison within the global LOICZ-Basins effort, although the entries to the tables can be different.

Up-scaling process

Drivers ranked for importance by expert judgement

Coastal issues	Drivers*	Local catchment level (allowing within- and between-catchment comparison)		Sub regional level (e.g. by country or considering open versus enclosed seas)		Region level (e.g., Asia)
Eutrophi-cation	Damming	River A	Trends or Ranking	Sub-region 1 (Rivers A-D)	Trends or Ranking	
Erosion	e.g. Water Abstraction	River B				
Loss of Biodiversity						

* = see comments on this driver identification and ranking on the following pages.

Figure A1.2. Basic schema of assessment tables.

Ranking and classification

The OSPAR 2000 quality status report (http://www.ospar.com) lists human pressures on the coastal sea in a ranking order with four classes according to their relative impact on the regional ecosystem - including sustainable use. Pressures are attributed to various drivers or pressure classes.

Table A1.1 shows some examples compiled along the OSPAR guidelines, adapted to fit the LOICZ-Basins concept. It focuses on issues which link to land-based activities.

Table A1.1. Examples of impacts, pressures and driver/pressure settings in the LOICZ context.

Impact priority	Priority classes of human pressures	Driver/pressure settings - sectoral; land- or catchment- or sea-based
A (highest impact)	Input of organic contaminants – land-based	Various economic sectors
	Inputs of nutrients – land-based	Various sectors, urbanization, (wastewater, agriculture)
B (upper intermediate impact)	Input of oil and PAH – land-/sea-based	Oil industry/Shipping
	Input of other hazardous substances – land-/ sea-based	Industry/Shipping/various sectors
C (lower intermediate impact)	Input of nutrients, organic material, antibiotics etc.	Mariculture
	Mineral extraction – land/ sea based	Engineering, Mining
	Inputs of radio nuclides from land	Energy and other sectors
D (lowest impact)	Input of waste/litter	Recreation, Tourism

From these and other examples, adapted to the LOICZ needs and relying strongly on regional expert judgement and - if available - regional quality standard protocols and agreements, the LOICZ-Basins task group has developed a set of **LOICZ-Basins Regional Assessment tables** for global application.

LOICZ-Basins Regional Assessment Tables (RA 1- 7) and key questions for workshops, synthesis and project development

The tabulated DPSIR analysis has proven to be an appropriate descriptive framework for this purpose. The questions leading through the tables have usually been addressed in the first phase of the LOICZ-Basins workshops. The tables ensure a standardized approach within the global LOICZ-Basins effort. They allow integration of the regional assessments and expert typologies into the global scales and help to fill gaps and harmonise the synthesis. Data included in the first workshop are reviewed and confirmed in light of new information delivered to the second workshop. Detailed source references for data or critical load information is included wherever possible (they can, however, also rely on expert knowledge to a considerable extend). The steps taken are outlined in the accompanying Regional Assessment (RA) tables.

Table Input

Major data needed for the assessment are material flows and loads (historic data and those of relatively unimpacted systems if possible). Fluxes to be considered are:

- Water
- Sediments
- N, P, C (Si)
- Contaminants

The trend information on expected changes in the DPSIR scenarios across the various scales (how will drivers change and will this affect the loads to the coastal sea?) provide preliminary assessment that sets the stage for dynamic scenario analysis.

The critical thresholds information can be derived from: ecological (State/Impact relationship) as well as political and managerial information (Response) which refers to environmental quality standards, regulations, water directives and other comparable instruments.

Table AI.RA1. Major coastal Impacts/issues and critical thresholds in coastal zones – Overview and qualitative ranking based on change in the region following the key questions

- What are major impacts (coastal issues) along the coastal zone?
- How close are they to a critical threshold of system functioning?

Coastal impact/issue e.g.	Local site/region (contributing river basins) e.g.	Critical Threshold (for system functioning) e.g.:	Distance to Critical Threshold (qualitative or quantitative) e.g.:	Impact category (Impact code and rank of importance 1- 10)	References/ data source
Erosion (coastal geomorphology)	River ABC - Delta	• For coastal stability; Sustained delivery of xy t per year • …..	Qualitative or quantitative information. about the amount needed for coastal security. (e.g., no distance since the sediment delivery due to damming has been reduced to such a level that coastal erosion becomes a continuos process)	Erosion - 10	Database xyz, Reference abcd, 19……
Eutrophication (habitat loss)	Bay ACEF – (rivers draining into the Bay a,b,c,…)	• Seagrasses show signs of destruction; • Occurrence of anoxia or low oxygen in estuaries; • Nutrient load is at the threshold.	Further increased nutrient load by 20-30% will change the system	Eutrophication - 8	
Pollution	Rivers XYZ				

Notes for use

This table is a first priority list of issues for the regional coast based on riverine (i.e. catchment-based) forcing. It serves to compile as much information as possible on critical fluxes, loads and thresholds for systems functions. It provides a first overview of a remaining capacity for material input or withdrawal that a target ecosystem might be able to handle without observable change. This can refer to a single function such as the stability of a coastal area against erosion. It can also refer to a multicausal impact affecting for example fisheries or water quality. These critical load and threshold estimates return in tables 6 and 7 as part of the "hot spot" and response assessment.

The ranking involves 4 main categories: values 1-3 no or minor importance, values 4-6 = medium importance, values 7-9 = major importance and value 10 = critical.

Table AI.RA2. DPSI matrix characterizing major catchment-based Drivers/Pressures and a qualitative ranking of related coastal State changes impacting the coastal zone versus catchments size class.

State change dimension: major; medium ; minor ; no impact; ? = insufficient information.
Time scale: p = progressive (continuous); d = discrete (spontaneous) n.a. = not applicable

Key questions and examples:

- What are the major (max. 10) driver/pressure settings on river catchment level causing coastal change?
- Can we identify spatial scales on which certain driver/pressure settings dominate coastal issues?

Driver	**Pressures**	**State change (qualitative index)**				**Impact on the coastal system**	**Time scale**
		Large basins	**Medium basins**	**Small basins: active coast**	**Small basins: passive coast**		
Agriculture	▪ Waste/nutrient (excess fertilizer) ▪ Increasing sediment transport ▪ Water extraction	**minor**	**medium**	**major**	**major**	▪ Eutrophication; ▪ Contamination; ▪ Siltation, etc….	**p**
Damming	▪ Nutrient and sediment sequestration ▪ Changing hydrological cycles	**?**	**major**	**n.a.**	**medium**	▪ Coastal erosion; ▪ Nutrient depletion; ▪ Salinization	**d**
Deforestation	▪ Sediment budget alteration ▪ …..	**minor**	**major**	**major**	**major**	▪ Siltation; ▪ Sediment accretion/ Erosion	**p**
etc	**etc**					**etc**	

<u>*Notes for use*</u>

Please refer to the basins in your sub-region or for which you have information and make a judgement on how intense the effects of the various drivers on these catchments are and to what extent this may impact on the coastal zone. Ranking is in three categories (also used in tables 1 and 3-5); those are: minor importance equals 1-3, medium importance equals 4-6, major importance equals 7-10.

State changes in coastal zones driven by a catchment – based prozess will vary according to catchment size, for example: Deforestation even on large scale if conducted in a huge catchment such as the Yellow or Yangtze will cause a rather moderate if any coastal signal as compared to effects originating from pressures on small catchments where even minor deforestation can dramatically influence the sediment budget in the coastal zone. So, deforestation in some large catchments could be scored a "minor" while in a small catchment it could go score a "major" ranking. Where your information is referring to only one catchment type or class (e.g., large >200.000 km^2, medium 10.000 – 200.000 and small <10.000 km^2), delete or ignore the other columns.

Active/passive coast refers to geomorphology, tectonics and climate. Small rivers along the Vietnamese coast for example are in a tectonically rather passive area with high seasonality in runoff (monsoonal influence) while small rivers draining to other coastal areas e.g. the Island of Taiwan or the Japanese Archipelago are located in a tectonical rather active area exhibiting high slopes but they also feature high amplitiudes of seasonal runoff variation on a yearly time-scale.

Table AI. RA3. Linking coastal issues/Impacts and land based Drivers in coastal zones – Overview, qualitative ranking and trend expectations on local or catchment scale.

Key questions:

- What are the major pressure/driver settings at catchment level causing coastal impacts?
- What are the future trends (based on hard data or expert judgement)?

Coastal Impact/issues	Drivers	Local catchment (allowing within and between catchment comparison)		Trend expectations	References/ data sources
		River A	Category (1 low – 10 high)		
Erosion	Damming	• Area… • Volume… • Runoff reduction… • …..	10	Increasing	XYZ, 2000
	Deforestation	• Area… • Residual TSS production… • …..	8	stable	
	Diversion	• Little, area; effect on water flow… • …..	4	decreasing	
Erosion total	All drivers	In River A	Ranking weighted from information above	Overall trend	
		River A	Category		
Eutrophication	Agriculture	Residual nutrient production…	9		
	Mariculture	Local residual nutrient production…	5		
	Municipal waste	Local urbanisation areas… ; xy t/tear residual production	10		
Eutrophication total	All drivers	In River A	Ranking weighted from information above	Overall trend	
Further issues					
etc					

Notes for use:
After finishing River A, continue with River B,C etc. Where possible please treat pollution separately from eutrophication.
The ranking involves four main categories: values 1-3 = no or minor importance; values 4-6 = medium importance; values 7-9 = major importance and value 10 = critical.

Table AI.RA4. Linking coastal issues/Impacts and land-based drivers in coastal zones – Overview, qualitative ranking and trend expectations on country or sub-regional scale.

Key questions and example:

- What are the major pressure/driver settings on country or sub-regional level causing coastal impact observed?
- What are the future trends (based on hard data or expert judgement)?

Coastal impact/issues	Drivers	Sub-regional (i.e. by country or comparing open versus enclosed seas)		Trend-expectation	References/ data sources
		Sub Region A	Category (1 low – 10 high)		
Erosion	Damming	• Catchments involved • Area… • Volume… • Run off reduction…	5	stable	
	Deforestation	• Area… • Residual TSS production…	8	increasing	
	Diversion	• Little, area…; effect on water flow…	4	increasing	
Erosion (total in sub-region A)	All drivers and rivers weighted	Sub Region A	Ranking weighted from information above		
Eutrophication	Agriculture	Residual nutrient production…	9		
	Mariculture	Local residual nutrient production…	5		
	Municipal waste	Local urbanisation areas… ; xy t/year residual production	10		
Eutrophication (total in sub-region A)					
etc.	**etc.**	**etc.**			

Notes for use:

If you have information about more than one sub-region e.g. north-west Africa or north-east Brazil, please treat them separately. Information involved here should summarize the coastal issues for the whole region and consider all the rivers reaching the coast.

The ranking involves 4 main categories: values 1-3 = no or minor importance, values 4-6 = medium importance, values 7-9 = major importance and value10 = critical.

Table AI. RA5. Linking coastal issues/Impacts and land-based Drivers in coastal zones – Overview, qualitative ranking and trend expectations on whole regional or continental/sub-continental scale.

Key questions:

- What are the major pressure/driver settings at whole regional, continental/sub-continental level causing coastal impact observed?
- What are the future trends (based on hard data or expert judgement)?

Coastal impact/issues	Drivers	Full regional (continent or sub-continent)		Trend-expectation	Reference/ data source
		e.g. Asia or East Asia	Category (1 low – 10 high)		
Erosion	Damming	• Sub-regions involved • Area… • Volume… • Runoff reduction…	2	increasing	
	Deforestation	• Area… • Residual TSS production…	8	stable	
	Diversion	• Little, area; effect on water flow	4	increasing	
Erosion (total in the region)	All drivers and rivers weighted	Full region scale	Ranking weighted from info above		
Eutrophication	Agriculture	• Residual nutrient production…	4		
	Mariculture	• Local residual nutrient production…	5		
	Municipal waste	• Local urbanisation areas… ; xy t/tear residual production	10		
Eutrophication (total in the region)					
etc.	**etc.**	**etc.**			

Notes for use:
This table should be filled in during the workshop since it will help synthesising the working group discussions on up-scaling individual catchment and sub-region based information. The ranking involves 4 main categories: values 1-3 = no or minor importance, 4-6 = medium importance, 7-9 = major importance and 10 = critical.

Table AI.RA6. Scientific and/or management Response to coastal impact/issues in (continental region) coastal zones on catchment, sub-regional and regional scale.

Assessment of scientific and/or management Response on the various scales: overview of monitoring programmes and scientific investigations as well as (if applicable) management interventions, environmental quality standards, legislation, river and other commissions).

Key questions:

- What is the current status of response taken at scientific policy and/or management levels against the major coastal issues in the region?

River catchment	RESPONSE catchment scale		RESPONSE Sub-regional/ country scale		RESPONSE Regional scale	
	Scientific	**Management**	**Scientific**	**Management**	**Scientific**	**Management**
River A	e.g. monitoring programme 19--2001, Data: …; Source:	e.g. commission established; thresholds set; legislation in place… Source:	e.g. (combining catchments A-B-… Programs? Data? Source:	e.g.…	e.g. UNEP Regional Seas programme Source:	e.g. quality criteria for the regional waters? Source
River B						
River C						
River D						
River E						

Notes for users:

This table describes the current activities dealing with the issues on either a scientific or a policy level. This can include databases and monitoring efforts, local GOOS networks or simply investigations. On policy and management levels, this focus can be on guidelines, threshold values and environmental standards (political critical loads). The scale to which these measures are being applied or should apply should be mentioned.

The information and ranking of DPSIR scenarios (tables 1-5) together with this "Response" information should lead to the identification of "hot spots" to be listed in Table 7.

Table AI.RA7. "Hot spots" of land-based coastal Impact and gaps in understanding; a first overview of issues to be addressed in future research (identifying the appropriate scale for the design of a new scientific effort).

Key questions:

- What are the major gaps in our current understanding of river catchment - coastal sea interactions?
- Which "hot spots" should be addressed in a future integrated scientific effort (natural and socio economic disciplines)

River catchment	"Hot spot" catchment scale		"Hot spot" sub-regional/ country scale (e.g. Yangtze River or Bohai Sea)		"Hot spot" regional scale	
	Key issues, trend and gaps	**Scientific approach**	**Key issues, Trend and gaps**	**Scientific approach**	**Key issues, Trend and gaps**	**Scientific approach**
River A	…	• Biogeochemical studies • Residual calculation by economic sectors • Critical flux investigation • Stakeholder and scale analysis • ACTION • ….		e.g.…	…	…
River B						
River C						
River D						

Notes for use:

This table extracts from the regional assessment the potential demonstration sites, which can be included in a proposal for a future Regional Catchment/Coast Assessment Project - "…Cat". Ideally the sites should represent different settings which are typical for a special sub-region. This would allow up-scaling of the findings to comparable "classes" of catchment/coastal systems at a later stage. An accompanying note may be given informing about ongoing activities, link suggestions and key contact persons.

Emphasis should be on the human dimensions of catchment–coastal sea interaction considering the co-evolution of natural and societal systems (i.e. involving natural and socio-economic sciences).

Appendix II. Meeting report

East Asia Basins Workshop

The East Asia Basins workshop held in Hong Kong 26-28 February 2001 was the first workshop to apply this methodology developed in the LOICZ Basins questionnaire. It generated an up-to-date overview of coastal change issues in the region which can be attributed largely to catchment-based drivers. During this workshop, a scientific and institutional network was established, including representatives of six countries from the region. Three sub-regional working teams were established, one covering the largely sub-tropical area around the South China Sea, a second the more temperate and stream-dominated East China Sea and a third the northern sub-region of the Sea of Okhotsk. The workshop concentrated on establishing a data and information base consisting of the existing knowledge and the major gaps in "catchment–coastal sea" interaction issues.

In recognition of the unifying geographical features, the human pressures and the "island situation", information on riverine fluxes to the sea and change from catchments located in Taiwan and the Japanese Archipelago were considered as larger spatial sub-units. The DPSIR (Drivers, Pressure, States, Impacts, Response) scheme provided a practical framework facilitating the review of drivers of change at the catchment level and the identification of and first efforts to categorize key pressures on the coastal systems.

Representatives of the Chinese Academy, the National LOICZ Committee and the LOICZ representative opened the meeting and underlined its key role in regional research on global coastal change. Dr Hartwig Kremer (LOICZ) introduced the general background and approach in the LOICZ-Basins assessments project, highlighting the pilot role of this workshop and region for global implementation. Addressing the issues of coastal change and human dimensions in the East Asian region involves synthesis of complex land-sea interactions in one of the fastest growing economic regions of the world, which includes several of the most important rivers globally. Significant demographic pressures in large parts of East Asia parallel the global forcing functions of environmental change. Human adaptation to achieve sustained quality of living thus continues to reflect in land and water use (river management) changes, which affect the coastal zone as the major receiving body of the horizontal water continuum. IGBP through LOICZ is trying to provide a first global overview of these catchment-based pressures and how they affect the environmental systems of the coastal zone and thus the goods and services provided by the coastal ecosystem.

East Asia Basins is the fourth regional effort, following Europe, South America and Africa, to assess how horizontal material fluxes of nutrients, carbon and contaminants determine the state of the coastal systems, how this is perturbated by global and human forcing and what the expected trends for the near and mid-term future are. It uses the catchment scale to explain the state of the coast and uses the Drivers-Pressures-State-Impact-Response framework (DPSIR) as a standardized approach for site description and upscaling.

To allow upscaling of the findings to sub-regional, regional and global scale, the LOICZ assessment and analysis approach would provide the synthesizing information in a way comparable to other regional efforts. One additional focus was therefore directed – based on expert judgement and hard data as available – towards the development of a qualitative ranking of the various drivers and pressures, states and impacts that can be used for typological comparison. By employing (for the first time) a set of interrelated regional assessment tables for the synthesis, this workshop entered a new field, indicating also LOICZ development of integrated and multidisciplinary assessment. In parallel, the typology approach and tools developed by LOICZ allows for testing of the applicability of Basins information; this will be a task for future research efforts.

The workshop generated four levels of products:

1) the regional overview reported and published here as part of the series of LOICZ Reports and Studies Volumes (R&S); this report will contribute to the first LOICZ synthesis to be published in 2003. It provides a set of standardized assessment tables with a sectoral analysis of drivers, pressures on the water systems and critical thresholds for system functioning going with and expert analysis of trend expectations. The distance of material fluxes to critical thresholds is presented in first order qualitative ranking based on estimates and hard data where possible. Gaps in current understanding and hot spots are provided and literature references are given where possible. The tables cover catchment, sub-

regional and full regional scales, providing a hierarchy of scientific information across those spatial and temporal scales identified by the network as the most appropriate. Fluxes considered are those of water, sediments, nutrients, some waste and heavy metals;

2) a regional network of scientists and institutions involved in this special LOICZ core project but also involved in other investigations of global and regional coastal change issues;
3) the scientific basis – following the identification of regional hot spots and gaps in current scientific understanding of the human and global change effects on the river–coast systems – from which to derive proposals for integrated assessment and modeling to be developed by the network and its members;
4) a special issue of a peer-reviewed journal, incorporating extended executive summaries of the R&S volume. Focus will be on biogeochemical and human dimensions of coastal changes, giving a holistic picture of environmental functioning. This volume is currently in the review and editing process for "Regional Environmental Change" published by Springer.

The projects under 3 can benefit from using current and future LOICZ tools in both the biogeochemical and socio-economic fields as well as building on earlier interdisciplinary efforts such as the modelling of residual productions of material fluxes as in the South East Asian project, SWOL (LOICZ R&S 17). Proposals can also be developed in consultation with other LOICZ-Basins projects such as EuroCat (http://www.iia-cnr.unical.it/EUROCAT/project.htm).

Dissemination of the information will be valuable for other global efforts such as the Global International Waters Assessment (GIWA), driven by UNEP/GEF, as well as to intergovernmental bodies, e.g., UNESCO's IOC (coastal GOOS and ICAM initiatives) as well as institutions involved in management issues on various levels. In this respect a crucial role was seen for the Asia Pacific Network for Global Change, APN, which together with START and IOC supported the workshop. Given its mandate to provide the regional link between science and application, this intergovernmental network would be of significant importance to help broker the issues and scientific results between the scientific community and the users at various levels. The Global Change System for Analysis, Research and Training, START, was considered to provide a platform on which to enable regional training and capacity-building to match the expected needs for integrated modelling, upscaling and application.

East Asia Basins and LOICZ expressed their special thanks to Professor Ming H. Wong and his team for the excellent organization, support and hosting of this crucial meeting. Efforts undertaken on national scales prior to this meeting such as the East Asia LOICZ workshop held in Qingdao in October 1999, which set the stage for this Basins workshop and the regional LOICZ engagement, were gratefully acknowledged. The Meeting also expressed its gratitude to the co-funders of this workshop namely the APN, START and UNESCO's IOC.

Appendix III. East Asia Basins workshop: List of participants

China
Professor Shu Gao
22 Hankou Road
Department of Geo-Ocean Sciences
Nanjing University
Nanjing 210093
China
Phone: +86 25 359 7082 (o); 3078 (h)
Fax: +86 25 359 2686
Email: shugao@nju.edu.cn

Professor Lijie Pu,
Department of Geography
Nanjing University
Nanjing 210093
China
Phone: +86 25 3593562
Fax: +86 25 3307923
Email: ljpu@nju.edu.cn or
ndszb@nju.edu.cn

Professor Ming H. Wong
Institute for Natural Resources and Waste Management
Hong Kong Baptist University
Kowloon Tong
Hong Kong SAR, China
Phone: +852 23307050
Fax: 852 23395995
Email: mhwong@hkbu.edu.hk

Dr Chaoyu Wu
Center for Ocean Research
Zhaongshan University
Guangzhou GD 510275
China
Phone: +86 20 84113644, 84113678
Email: eeswcy@zsu.edu.cn

Dr Guangxi X. Xing
Institute of Soil Science
Chinese Academy of Sciences
Nanjing 210008
China
Phone: 86 25 3360874(o); 3361026(h)
Fax: 86 25 3353590(o); 3361026(h)
Email: xinggx@ns.issas.ac.cn

Professor Zuosheng Yang
Ocean University of Qingdao
5 Yushan Road
Qingdao 266003, PR. China
Fax: 86 532 2032799
Email: zuosyang@public.qd.sd.cn

Germany
Dr Horst Behrendt
Institute of Freshwater Ecology & Inland Fisheries
Dept of Flatland Rivers & Shallow Lakes
Mueggelseedamm 310
D-12587 Berlin
Germany
Tel: +49 30 64181683
Fax: +49 30 64181799
Email: behrendt@igb-berlin.de

Japan
Dr Yoshiki Saito
Marine Sedimentology Section
Marine Geology Departement
Geological Survey of Japan
Higashi 1-1-3,
Tsukuba, Ibaraki, 305-8567
Japan
Phone: +81 298 613772
Fax: +81 298 613747
Email: yoshi@gsj.go.jp

Dr Masataka Watanabe
Director
Division of Water and Soil Environment
National Institute for Environmental Studies
16-2 Onogawa,
Tsukuba, Ibaraki
Japan
Phone: 81 298 50 2576
Fax: 81 298 50 2576
Email: masawata@nies.go.jp

Korea
Dr Gi-Hoon Hong
Marine Biogeochemistry and Isotopes
Korea Ocean Research & Development Institute
Ansan P.O.Box 29, Seoul 425-600
Republic of Korea
Phone: +82 2863 4770 319
Fax: 82-345 408 4493
Email: ghhong@kordi.re.kr

Netherlands

Dr Hartwig Kremer
LOICZ IPO
P.O. Box 59
1790 AB Den Burg
Texel
The Netherlands
Phone: 31 222 360 404
Fax: 31 222 360 430
Email: loicz@nioz.nl

Norway

Jozef Pacyna, (LOICZ SSC)
Norwegian Institute for Air Research NILU
PO Box 100
Instituttveien 18
N-2007 Kjeller,
Norway
Phone: 47 63 89 8000
Fax: 47 63 89 8050
Email: jp@nilu.no

Russia

Professor Dr V.V. Anikiev
Chief of ecological Safety Laboratory
State Scientific Center
All Russian Research Institute of Geosystems
113105 Varshavskoye shosse, 8
Moscow,
Russia
Phone/Fax: 7-095-9583211
E mail: anikiev@mail.ru

Dr Anatoly N. Kachur
Director of Centre for Landscapes and Environmental Studies
7 Radio Street
Vladivostok 690041
Russia
Phone: 7 4232 311-117
Fax: 7 4232 312-833
Email: akachur@mail.primorye.ru

Taiwan

Prof. Chen-Tung Arthur Chen
Institute of Marine Geology and Chemistry
National Sun Yat-sen University
Kaohsiung 80424
Taiwan
Phone: 886 7 5255146
Fax: 886 7 5255346
Email: ctchen@mail.nsysu.edu.tw

USA

Casey J. McLaughlin
Geography Department
213 Lindley Hall
University of Kansas
Lawrence, KS 66045
Phone: +1 785 864 3965
Fax: +1 785 864 5317
Email: cjm@ukans.edu

Vietnam

Dr Nguyen Hoang Tri
Center for Natural Res. & Environmental Studies
Vietnam National University
No. 7, Ngo 115, Nguyen Khuyen
Hanoi, Vietnam
Fax: +84 4 733 5624
Email: nguyenhoangtri@hn.vnn.vn

Dr Tran Duc Thanh
Vietnam National Center for Natural Science & Technology
Haiphong Institute of Oceanology
246 Danang Street
Haiphong City, Vietnam
Tel: 84 31 760602
Fax: 84 31 761521
Email: tdthanh@hio.ac.vn

Appendix IV. Agenda - East Asia Basins Workshop, Hong Kong, 26-28 Feb 2001:

Mon. 26th Feb.

9:00 – 9:30 Registration

9:30 – 10:00 Opening Session:

East Asia LOICZ Committee	Prof. Shu Gao, Prof. Zusheng Yang
Local Host – Hong Kong Baptist University	Prof. Ming H. Wong;
IGBP/LOICZ, Focus 1 representative and LOICZ IPO	Dr. Hartwig Kremer

10:00 – 10:45 Introduction:

- LOICZ BASINS, background, approach, products and goals
- Upscaling – introduction into typology - Approach and products
- Timelines and Outlook

By: LOICZ/regional LOICZ/local host — Prof Jozef Pacyna, Dr. Horst Beherendt, Dr. Hartwig Kremer, Casey McLaughlin, Prof. Shu Gao, Prof. Ming H. Wong

10:45 – 11:00 *Tea Break (same time each working day)*

11:00 – 12:30 1. Plenary Session on Drivers, Pressures and State/State-Changes:
Presentation of Papers (see list attached)
Discussion and Summary

12:30 – 14:00 *Lunch (same time each working day)*

14:00 – 15:30 2. Plenary Session on Drivers, Pressures and State/State-Changes:
Presentation of Papers (see list attached)
Discussion and Summary

15:30 – 15:50 *Tea Break (same time each working day)*

15:50 – 17:30 3. Plenary Session – Wrap up:
Discussion and Strategy for the next days:

- how to fill the tables and synthesise on various scales (see attachment)
- organisation of break out groups (along division of the coastal zone and catchments for synthesis and upscaling by issues, size, drivers or country?)
- identify chairs and rapporteurs

If not already done in the groups, please find time to fill in the tables as provided and discussed in plenary and groups during the evening hours for report back tomorrow.

Tue. 27th Feb.Coastal Issues & land based forcing – catchment & larger scales

09:00 – 12:30 Morning and 14:00 – 17:30Afternoon max. 3 Break out groups (Chair & Rapporteur: TBA):

Assessment and synthesis of:

Issues/Impacts based on coastal change in the region of concern (table 1); maximal 10 major Driver/Pressure settings generating the coastal Impact/Issues (Table 2)

Links between coastal issues/impacts and land based pressures and drivers on catchment, sub regional and full regional scale (along tables 3 - 5 – see attachment)

Key questions:

- What are the major impacts (coastal issues) on the coastal zone and do we know anything on
- How close they are to a critical threshold of system functioning?
- What are the major (max. 10) driver/pressure settings on ctachment level causing coastal change?
- Can we identify spatial scales on which certain driver/pressure settings dominate coastal issues (relative classes in basins of different size for example)?
- What are the major pressure/driver settings on catchment level causing coastal impact observed and what are the future trends?
- What are the major pressure/driver settings on subregional or country level causing coastal impact observed and what are the future trends?
- What are the major pressure/driver settings on regional level causing coastal impact observed and what are the expected future trends?
- Can we develop a firstypology of catchment coastal sea interaction in east asia and what are the indices entering the typological comparisin (input in LOICZView)?

16:30 – 17:30 Plenary Discussion:

- Report back of the working groups;
- Drawing a qualitative or semi-quantitative, typological East Asia Basins picture;
- Introduction into the next day;

20:00 Conference dinner

Wed. 28th February:

09:00 – 12:00 Morning 3 Break out groups (Chair & Rapporteur: TBA):

short recall of the last day

Assessment of scientific and/or management RESPONSE on the various scales and
of major regional HOT SPOTS and GAPS in understanding, which seek further investigation in an holistic multidisciplinary scientific project - along tables 6 – 7 (see attachment)

key questions:

- What is the current status of response taken on scientific or policy/management levels against the major coastal issues in the region.
- What are the major gaps in our current understanding of river catchment - coastal sea interaction and which hot spots should be addressed in a future integrated scientific effort/proposal (natural and socio economic disciplines)

12:00 – 12:30 Plenary – report back from the working groups

Afternoon:

14:00 – 16:30 Afternoon max. 3 Break out groups (Chair & Rapporteur: TBA):

Discussion on sub regional or regional proposal/s:

16:30 – 17:30 Plenary

Report back from the project working groups
Approval of suggestions by the plenary (incl. commitments)
Launch of East Asia BASINS Network

Conclusion
Approval of product delivery timelines
Outlook

Close of the meeting

Appendix V. Terms Of Reference

LOICZ East Asia Basins Workshop on East Asian River Catchment/Coastal Zone Interaction and Human Dimensions (Impacts of land-based activities on coastal seas of East Asia)

Hong Kong, Baptist University, China, 26-28 February 2001

(Supported by IGBP/LOICZ, the Asia Pacific Network for Global Change (APN) and the Global Change System for Analysis, Research and Training (START)

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1) Introduction - the LOICZ-Basins Background

The discussion on global change issues in coastal zones and integrated coastal management focuses increasingly on the interplay between river catchments and the coastal sea. Coastal zone processes and health are reviewed much more as a systemic, i.e. receiving, part of the whole water continuum. This reflects in an increasing number of targeted programs and key actions such as the new European 5th Framework Program as well as among UNESCO, UNEP and GEF based/supported initiatives. The International Geosphere Biosphere Program, IGBP, responds through concentrating considerable effort on the human dimension of global change issues taking the whole water cascade as a scale. Parts of this issues are addressed in the "water group" initiative of IGBP, to which LOICZ since 1998 continues to contribute on various levels like the Sediment/Runoff Group (J. Syvitski) and the Basins core project (Wim Salomons, H. Kremer).

2) The Basins Strategy

In principle the LOICZ-Basins core project is working inter alia to develop a global evaluation of the importance of coastal seas as receiving bodies of land based changes of horizontal material fluxes such as carbon, nitrogen and phosphorus as well as water and sediments. The scale used for transport pathways incl. groundwater is the river catchments (or whole islands, if appropriate). Beyond giving an overview on coastal zone functioning as sink or source for nutrients and carbon, priority attention is paid to the relative importance of these materials and their biogeochemical cycles as indicators. In other words, to what extent do they represent environmental functioning and sustainability of goods and services provision under the dynamic natural and anthropogenic driven changing forcing functions. Assessment and modelling therefore aim to focus on residual transports of materials (C, N, P, sediments, others) as key indicators.

This is usually summarized as the a human dimension of coastal change. Therefore changing fluxes impacting the state of the environment and their feedback on the socio-economic system functioning are to be reviewed against the conceptual question of critical loads reaching the coastal zone and may be forcing systems to flip.

A challenging task in these workshops and synthesizing efforts is to focus on catchment based *drivers, pressures and state changes* (fluxes and material cycles) and to derive from those figures the *critical loads* based on

a) political regulations,

b) environmental monitoring including historical information and

c) stakeholder perception and requirements for coastal use (land and sea based).

The last steps are complex issues which might not be finally addressed in a first workshop. However, LOICZ's commitment to global synthesis of coastal change requires a serious basis for interregional and global comparison. It would therefore be quite recommendable to have at least a *qualitative or semi-quantitative set of indices of drivers and pressures* applied to a *catchment (island) scale* in place and to try to link them to change observed in the coastal zone. The latter refers to biogeochemical but also biological state parameters and should also encompass changes in human use such as sediment increase affecting aquaculture business for example. With a view on East Asia Basins and next year also South and South East Asia as well as Latin America (in a second run) these sets of categories and indices should be available until mid 2001.

The LOICZ-Basins information and index systems will subsequently be fed into a typological effort, allowing for the broader regional and finally global up-scaling. This typology effort is coordinated by Bob Buddemeier, LOICZ focus leader, Kansas Geological Survey, in co-operation with Charley Vörösmarty from the University of New Hampshire whose work is concentrating on global river runoff information as part of the IGBP BAHC (Biosphere Aspect of the Hydrological Cycle) programme.

As in other LOICZ-Basins efforts, East Asia Basins will continue to improve the standardization of approaches in addressing these issues in a holistic perspective. For this purpose, as appropriate for the various part-projects the simple DPSIR, *Drivers*, *Pressures*, *State* (State Change), *Impact*, *Response* scheme (OECD 1993 and LOICZ R&S No. 11 1998) will be applied as the underlying descriptive framework helping to sketch the various forcing functions and boundary conditions. In a mid term perspective this approach is seen to enable involvement calculation and modeling of effects on the delivery and use of environmental goods and services, their scientific and monetary expressions and to review the political *response* and options.

3) Links and Synergies

Within the broader context of the IGBP, LOICZ-Basins provides the scientific frame in which mid- and long-term collaboration with other core projects such as BAHC (Biospheric Aspects of the Hydrological Cycle), LUCC (Land Use and Cover Change) and PAGES (Past Global Changes) and with the IHDP will be developed and strengthened. Through the *Typology and Upscaling* efforts mentioned above LOICZ Basins has already established active co-operating with BAHC (see http://water.kgs.ukans.edu:888/public/Typpages/index.htm or www.nioz.nl/loicz/.)

With regard to science exploitation and application, as well as providing information for the global change questions, the issue-driven and human dimensions oriented character of LOICZ-Basins investigations on catchment or island scales and related coastal zones apparently has an implication for coastal zone management. Engaging with users in policy advisory groups and with the private sector therefore are requirements for the demonstration projects. In Europe there are examples for this in operation (LOICZ EuroCat project). Furthermore the approach taken and the results have potential to serve the objectives of intergovernmental organizations and in response Basins for example seeks strong working relations with UNESCO/IOC and its ICAM (Integrated Coastal Area Management) and C-GOOS (Coastal Global Oceans Observing System) programs. In Asia strong links to the APN (Asia Pacific Network of Global Change) are highly recommendable.

First steps in this direction were made at the 4th LOICZ Open Science Meeting in Bahia Blanca, Argentina, November 1999, and are intended to be continued through further collaboration with IOC. LOICZ-Basins demonstration sites are also pilot sites for C-GOOS and ICAM. Joint badging and future part support through IOC is intended. These links will allow a broad global application and evaluation of methods and modeling developed under LOICZ in a broad global context.

However, LOICZ-Basins results, particularly *Response* (i.e. policy and management response to coastal change) may also fertilize discussion on local management needs dealing with catchment/coast interaction issues or classes thereof. Response investigations can provide insight into how society acknowledges the *Pressure - State-change and Impact relation* and how this is reflected in success or failure of sustainable coastal management. A global synthesis experiment such as LOICZ can thus provide decision-makers with relevant scientific indicators and trend analysis to enable such judgements. It can also be a neutral platform for discussion and generation of joint ownership of issues among science and users. Examples in Europe are a Rotterdam – Rhine project forecasting sediment quality where LOICZ-Basins provides a scientific frame for trend analysis and interdisciplinary catchment scale approaches against concrete user needs.

4) Specific Workshop Objectives

1. provide a **state of the art report** of river catchment – coastal sea interactions and set up a first qualitative or semi-quantitative system to **categorise** key pressures and state change settings providing an **indexed data entry** for upscaling purposes on regional scale (see 2);
2. **upscale the information** to broader regional and finally global synthesis along the index system provided by identifying and clustering areas of similar change features using typology tools and the Drivers, Pressures, State, Impact, Response framework, DPSIR, for standardised site classification;
3. Provide the data and information base for an interregional/global LOICZ-Basins core project meeting of principal investigators, in second half 2001 aimed to combine the available regional information to an overall first *global LOICZ Basins synthesis;*
4. identify from the regional state of the art assessment and analysis a **set of focussed pilot areas,** for which to develop proposals (*optional for the regional network members*) for specific case studies integrating natural and socio-economic sciences aimed to elaborate on the "human dimensions" of global change along the whole water continuum;
5. **establish a regional East Asia Basins network** to continue the science and synthesis and to strengthen existing and seek new value added **links** to other projects and organisations such as UNEP, GIWA, IOC-UNESCO (GOOS and ICAM), START and IHDP. This will be facilitated through the LOICZ platform;

5) Focus of workshop:
To achieve the objectives outlined the workshop aims to work along the framework of the DPSIR scheme and focus on *assessment, analysis, categorisation and indexing* of :

a. Catchment-based activities (land use and land use change) with consequences for the coastal zone **(DRIVERS)** such as:

- Effects of damming and other huge constructions;
- River diversion and effects of irrigation and water supply activities (abstraction);
- Influence of industrial, agricultural and domestic wastes (urbanisation);
- Mining activities;
- other forcing functions such as climate change

b. Coastal zone activities (DRIVERS) and processes leading to degradation and coastal change in interaction with the catchment based factors, such as:

- Oil- and gas exploitation;
- Dredging and canalisation;
- Urbanisation and Large Scale (e.g. harbour) Construction and
- other forcing functions such as sea level rise as effected by land based activities

c. PRESSURES on key ecosystem and social system functioning; (indicating human pressures on the environment e.g. energy, industry, agriculture, fisheries) affecting the **STATE** and hence **changing** the **STATE** of the coastal environment due to natural and mainly anthropogenic forcing.
This is following the scientific guidelines in the LOICZ global synthesising experiment taking:

- Water, Nutrient and Sediment transportation throughout the catchments as key indicators for change across the boundaries of the water pathway. (Indicators are designed to give an overview of the environmental status and its development over time and finally allow the development of the critical load information and index systems linked to pressures);
- Geomorphologic settings, Erosion, Sequestration (retention times in the catchment) as well as
- Economic fluxes relating to changes in resource flows from coastal systems, their value and changes in economic activity

d. IMPACTS, which is effects on systems and how they are expressed, i.e. habitats, biodiversity, social and economic functioning and resource and services availability and use and finally the

e. RESPONSE reflecting action taken (coastal management) to either protect against change such as increased nutrient or contaminant input, secondary sea level rise by means of reduced sediment loads etc, ameliorate adverse effects and ensure sustainable use of system's resources.

6) Products and Expectations

The success of the Hong Kong workshop in February 2001 will lead the way to:

- Provision of the information necessary for the LOICZ *regional synthesis* the backbone of which will be a LOICZ R&S series volume along the workshop focus thus addressing the following suggested chapters:

LOICZ - R&S Report – East Asia - Basins – River Catchment/Coast Interaction in East Asia and Human Dimensions of Change

1. DRIVERS (Issues)
2. PRESSURES
    - 2.1 Development of qualitative indices
    - 2.2 Categorise the relevance of Pressures
3. STATES and STATE-CHANGES (Fluxes, Material cycles)
4. IMPACT (environmental and socio economic focus)
    - 4.1 Development of qualitative indices
    - 4.2 Categorise the relevance of Impacts
5. RESPONSE
    - 5.1 Socio-Economic and Political/Legal settings
    - 5.2 Changes of these settings
6. REGIONAL UPSCALING
    - 6.1 Typology development – Driver/Pressure/State/Impact/Response scenarios employing indices of the various aspects;
    - 6.2 Typology of the regional features;
7. TREND ANALYSIS
    - 7.1 Defining Change - the "Delta" - of key parameters and derive first trend prediction;
8. GAPS
    - 8.1 Data and Information gaps;
    - 8.2 Efforts/Commitments needed to fill these gaps;

- drafting of a *follow-up proposal* aimed at integrated cross-disciplinary, i.e. combining natural and social science, pilot studies complementing those under parallel development within the other regional Basins efforts *(optional for the regional network).*

(As outlined earlier a major criterion for their selection being the potential for upscaling which means that they have to represent the major classes of catchment - coastal sea systems and driver interaction that is characteristic for a bigger region in order to allow comparison on broader scales in the development and evaluation of the project)

- information flow into an interregional/global Basins core project meeting with the regional principal investigators involved, planned for second half 2001 is aimed to finally combine the available regional information to an overall first *global LOICZ Basins synthesis* and provide a draft outline for the respective LOICZ Synthesis Book Chapter.

In summary the East Asia Basins network established through the workshop will take responsibility for finalizing the regional synthesis and providing the umbrella for the set of interdisciplinary proposals coming out. Together with LOICZ and cooperating Agencies the network will pursue efforts to generate appropriate funding for the future work.

7) Workplan (tentative)

- The workshop is to be held 26-28 Feb 2001, in Hong Kong, Baptist University, China;
- Background documents, (LOICZ reports and further information will either be delivered prior to the meeting or made available through the web – LOICZ R&S No. 11 on Integrated Modelling and the DPSIR can be downloaded as a pdf file from http://wwwnioz.nl/loicz/ (extended executive summaries submitted to the organisers will as well serve as background discussion papers for the regional review);
- Proposed participants list will be circulated following the finalisation of the selection process;
- Products foreseen will be a LOICZ Reports & Studies Volume (R&S) published jointly with the partner organisations the draft to be prepared during the meeting and finalised within three months after the workshop. Special publications in peer reviewed journals are encouraged.
- Pilot areas will be identified at the meeting and drafting of the proposals will be optional for participants as a follow on with timelines to be set up individually.
- Timeline, TOR and potential host for a follow up East Asia Basin will be considered;

8) Participants

The scientists who have been or will be approached for expression of interest are:
Researchers from East Asia and elsewhere, who are exposed through their work field to issues mentioned. The workshop is supposed to be highly product oriented and attendance will therefore be limited to a maximum of 15 to 20 participants, including LOICZ resource scientists and organisers and plus technical secretarial support (preferably asked from the local organiser). Invitation and support will be based on scientific review of extended abstracts submitted to the organisers and evaluated by a the East Asia - Basins Scientific Committee.

9) Concluding Remark

In the first step we talk about qualitative and semi-quantitative assessment and categorization of pressures, state changes and impacts based on hard data input where already available. It seems likely, however, that the tentative chapters mentioned will seek further elaboration in a continued East Asia Basins effort – strongly reflecting on outcomes and interim tasks deriving from East Asia Basins.
From the beginning focus should be on linking in socio-economic information into the analysis and development of pressure – state – response indices as much as possible. This usually turns out to be the major challenge and biggest gaps in appropriate networking and should therefore be a priority issue in the process of network formation and further development.
In the process of verifying and approving demonstration sites for which to draft future holistic project proposals along the LOICZ design emphasis will have to be put on both, the potential to upscaling and management relevance.

10) Annex

A draft program for the workshop can be found in ANNEX I and some background information sketching characteristic geographical and river catchment features are summarized in ANNEX II.

Appendix VI List of acronyms and abbreviations used

BAHC	Biospheric Aspects of the Hydrological Cycle (IGBP core project)
C-GOOS	Coastal Module of the Global Ocean Observing System (IOC)
DEFINITE	DEcisions on a FINITE set of alternatives – software package developed by Janssen *et al.*, VU Amsterdam
DIVERSITAS	(An international programme of Biodiversity Science)
DPSIR	Driver-Pressure-State-Impact-Response assessment framework
EuroCat	European Catchment Studies
GEF	Global Environment Facility
GIWA	Global International Waters Assessment
GOOS	Global Ocean Observing System
HAB	Harmful algal blooms
ICAM	Integrated Coastal Area Management
ICARM	Integrated Coastal Area and River Basin Management
IGBP	International Geosphere Biosphere Project
IOC	Intergovernmental Oceanographic Commission of UNESCO
LOICZ	Land-Ocean Interactions in the Coastal Zone (IGBP core project)
LUCC	Land-Use/Cover Change (IGBP co-sponsored core project)
MONERIS	Modelling Nutrient Emissions in River Systems
NGO	Non-governmental Organisation
OECD	Organisation for Economic Cooperation and Development
PAB	Policy Advisory Board
PAGES	Past Global Changes (IGBP core project)
PAH	Poly aromatic hydrocarbons
PCB	Polychlorinated hydrocarbons
POP	Persistent organic pollutant
RMB	Renminbi – Chinese paper currency
SAmBas	South American Basins (LOICZ-Basins core project)
SAR	Special Administrative Region
SARCS	South Asia Regional committee for START
START	Global Change System for Analysis, Research and Training
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational Scientific and Cultural Organisation
WCRP	World Climate Research Program
WOTRO	Netherlands Foundation for the Advancement of Tropical Science
WP	Work Package
WWAP	World Water Assessment Programme