FIGURES

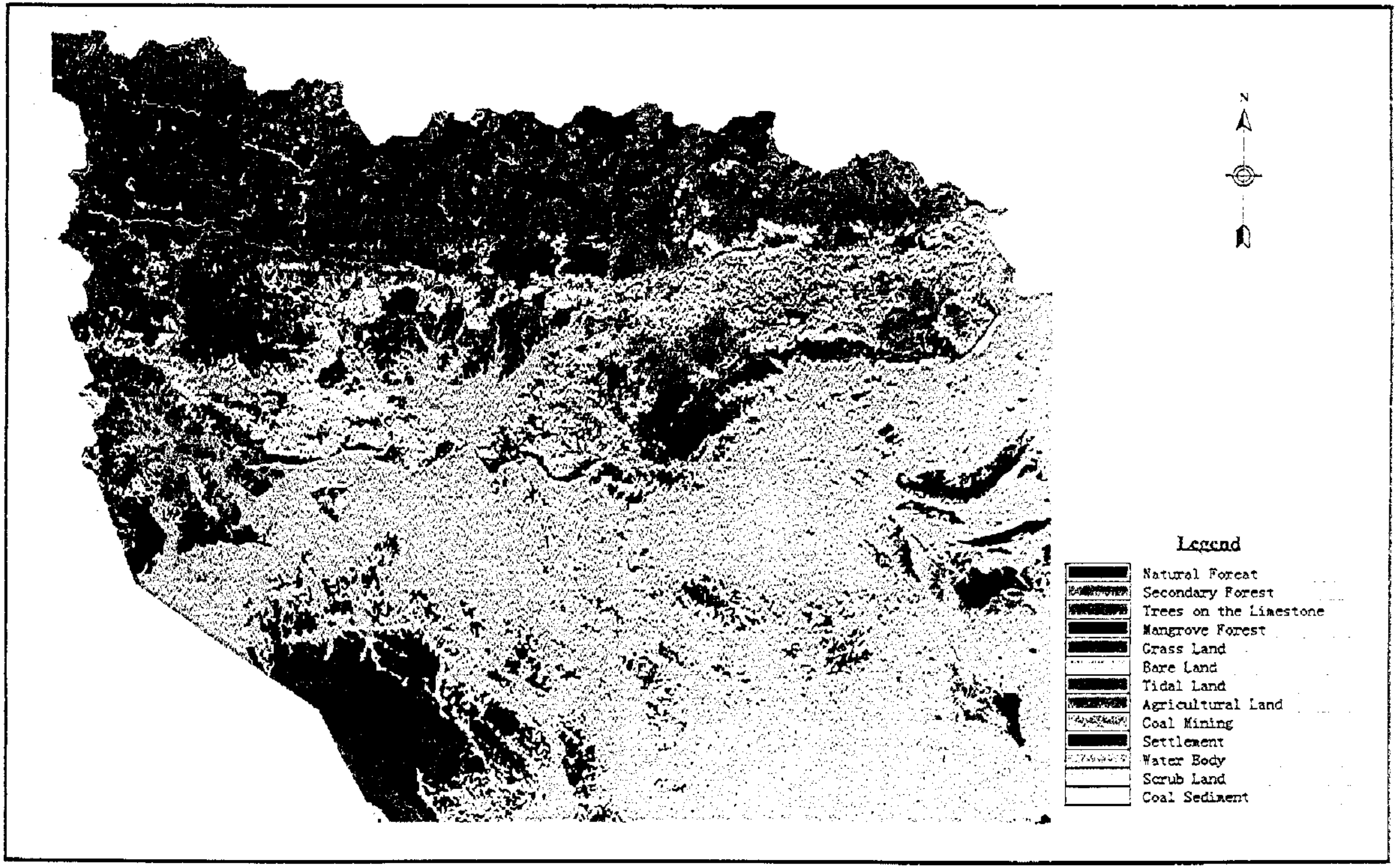


Figure 2.1.1 Latest Land Use Map by Satellite Image Analysis

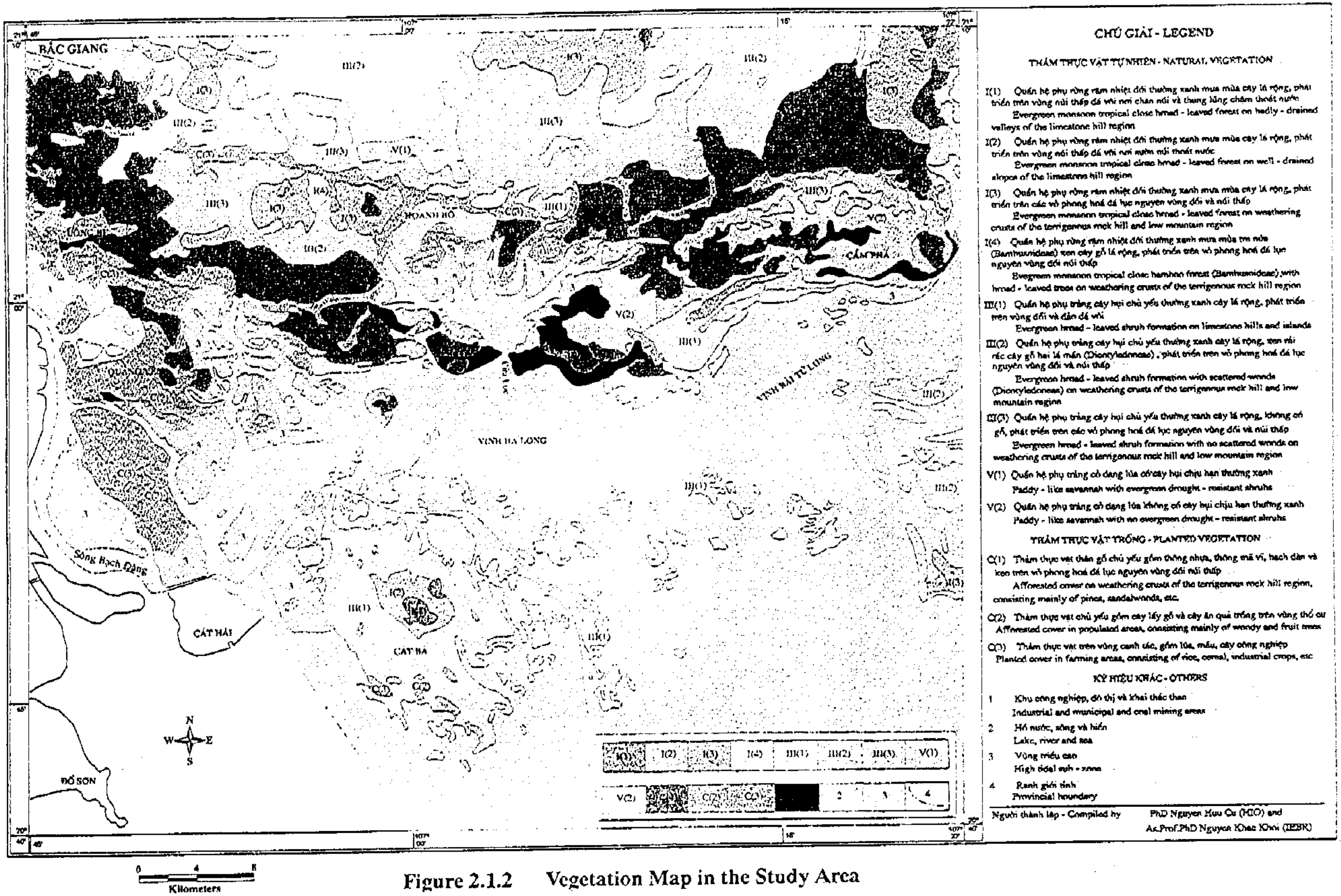
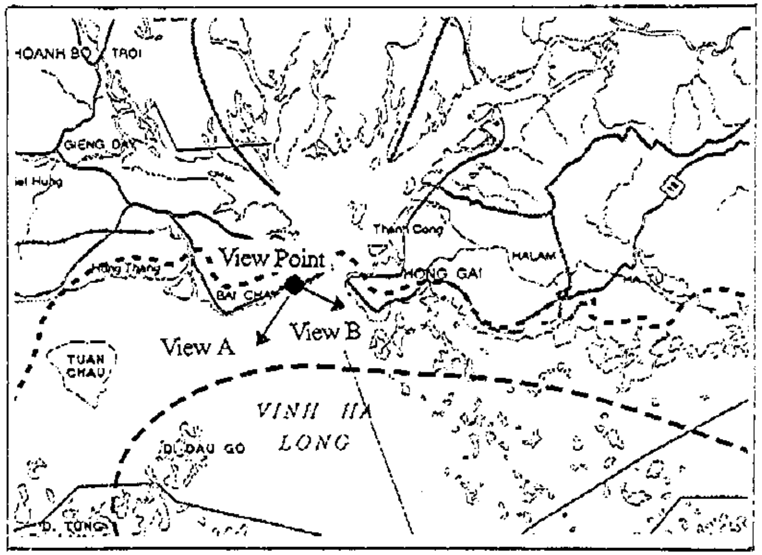


Figure 2.1.2 Vegetation Map in the Study Area

View Point : Beach in Bay Chay

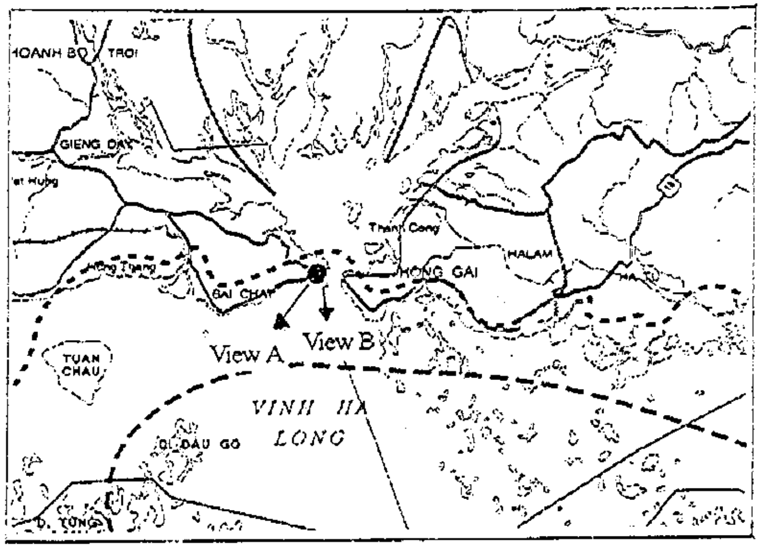


View A

View B

Figure 2.1.3(1) **Typical Landscape of Ha Long Bay World Heritage from Mainland**

View Point : Seaside Road in Bay Chay

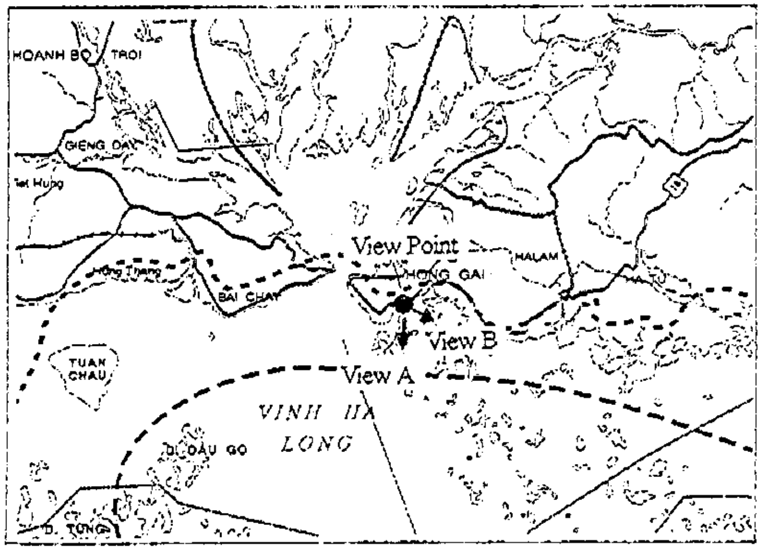


View A

View B

Figure 2.1.3(2) Typical Landscape of Ha Long Bay World Heritage from Mainland

View Point : Lan Be Park in Hong Gai



View A

View B

Figure 2.1.3(3) Typical Landscape of Ha Long Bay World Heritage from Mainland

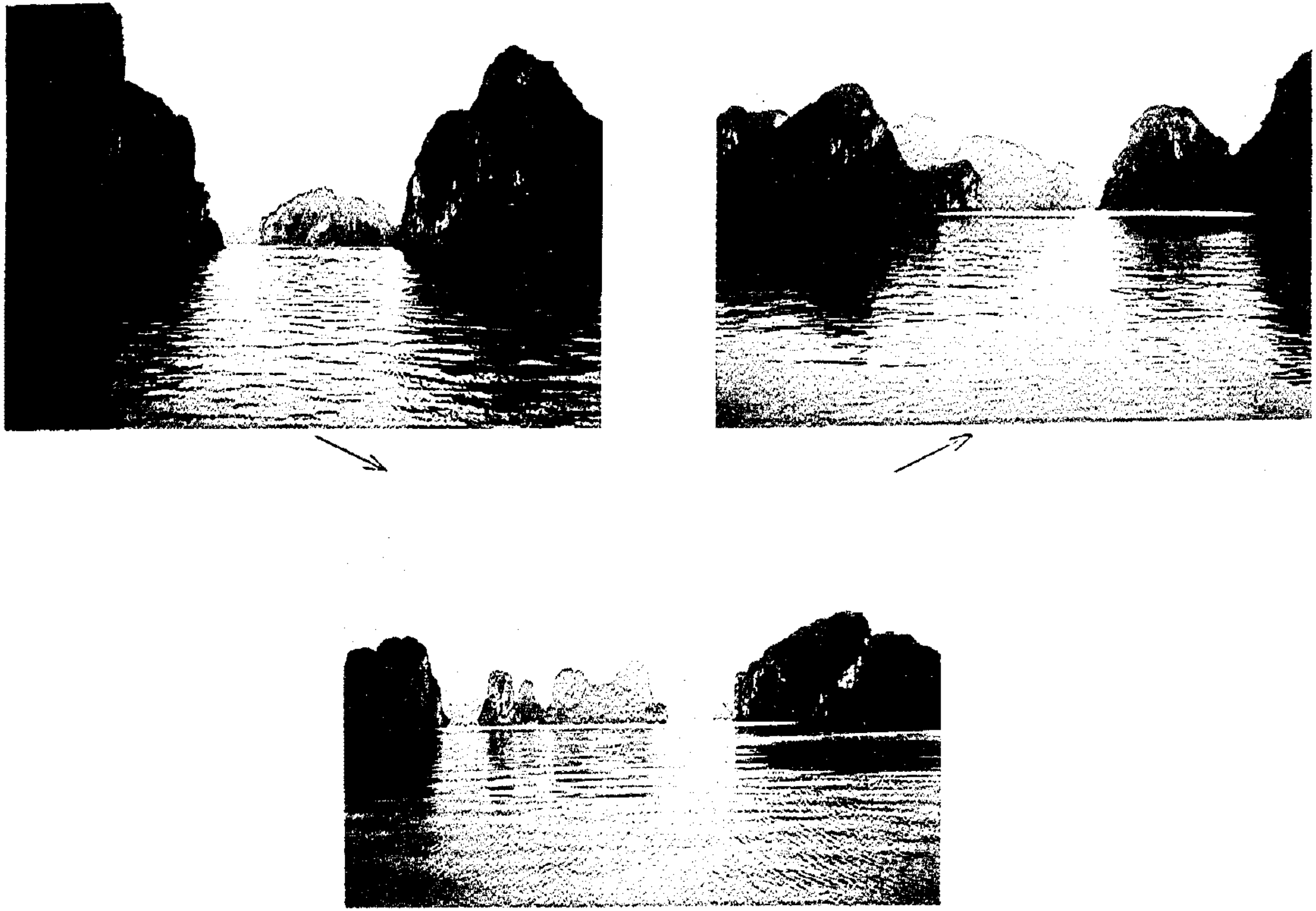


Figure 2.1.4 Typical Landscape of Ha Long Bay World Heritage from Boat

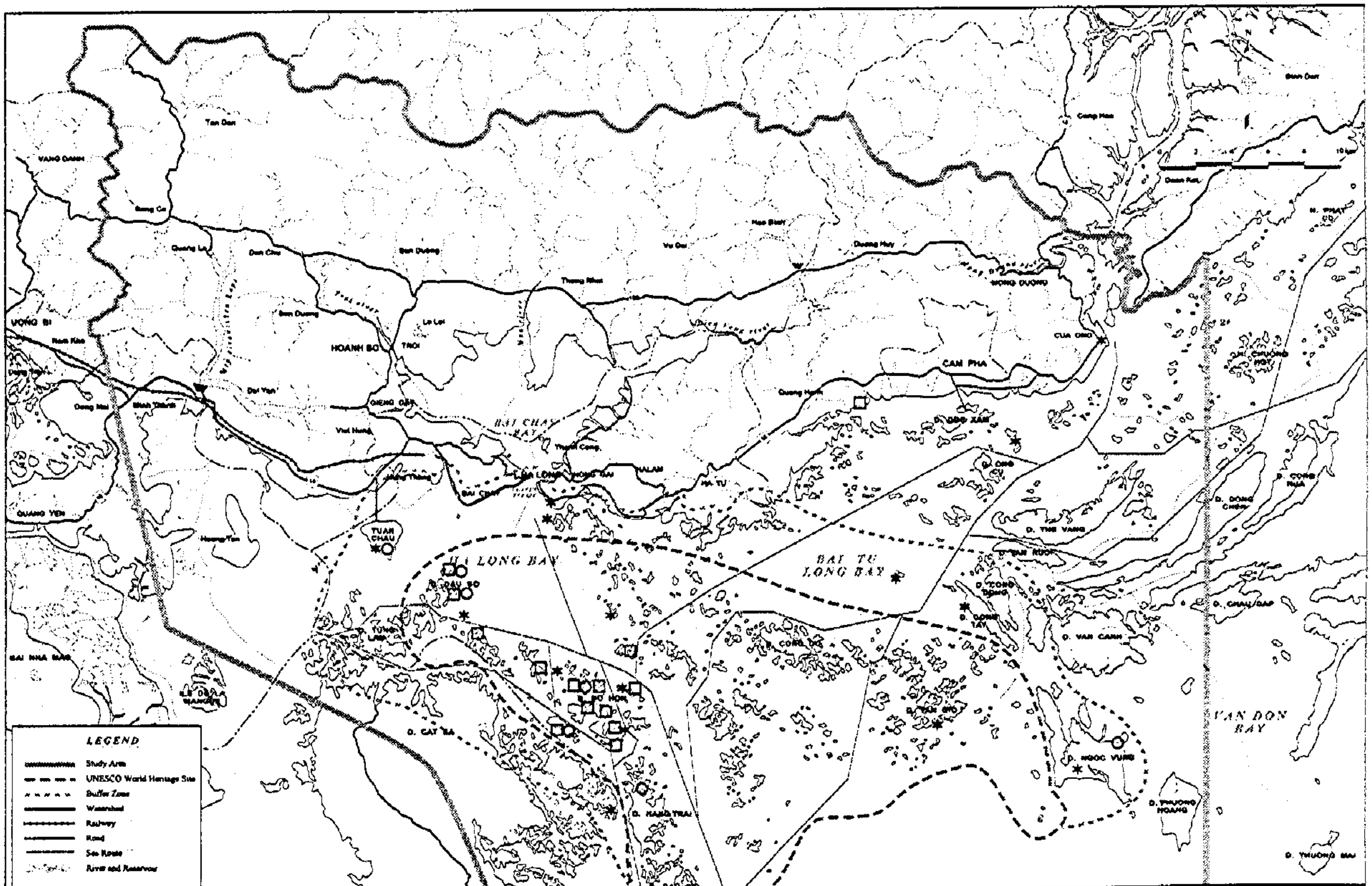


Figure 2.1.5 Tourism Spots in World Heritage Areas

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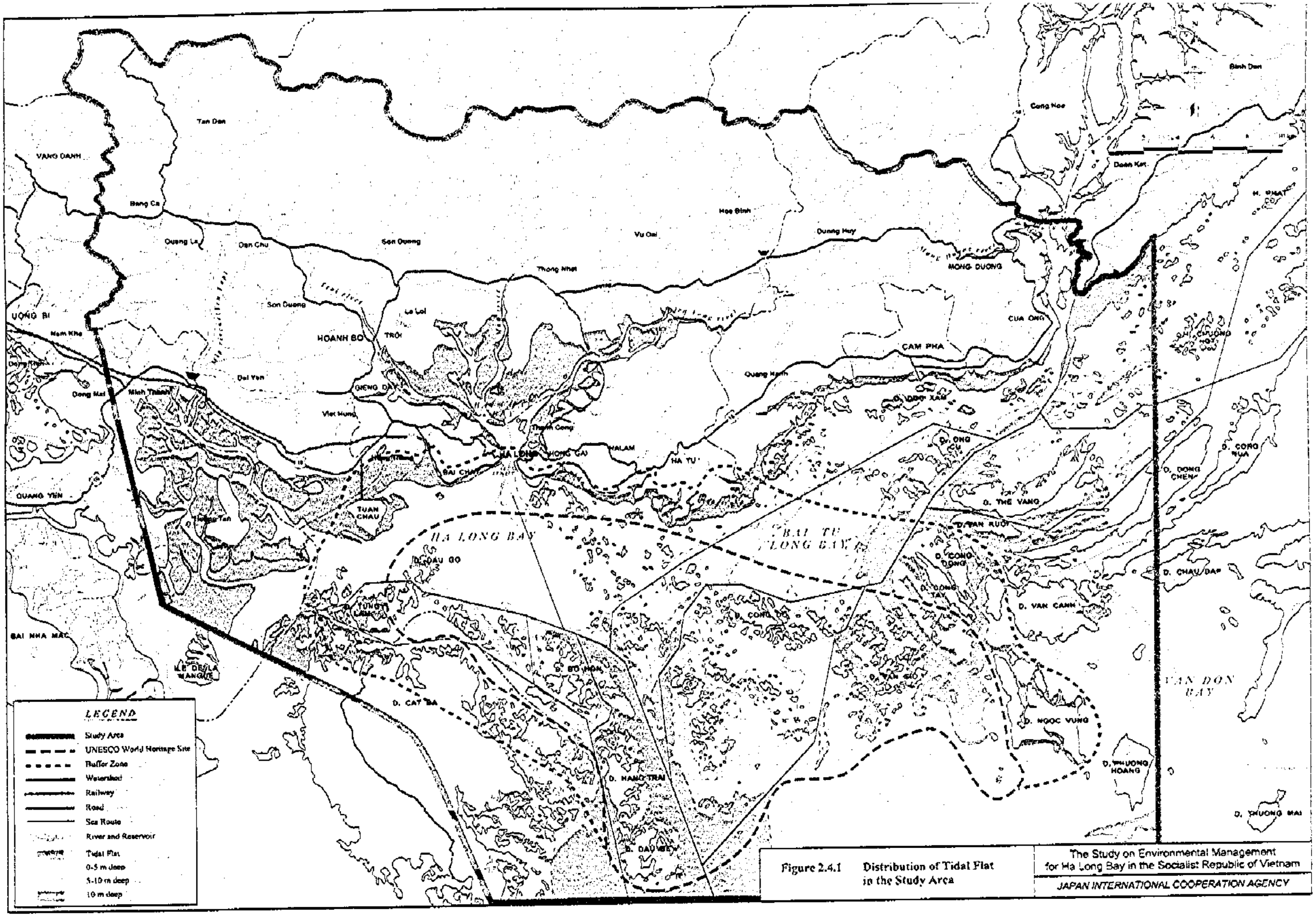

Figure 2.4.1 Distribution of Tidal Flat in the Study Area

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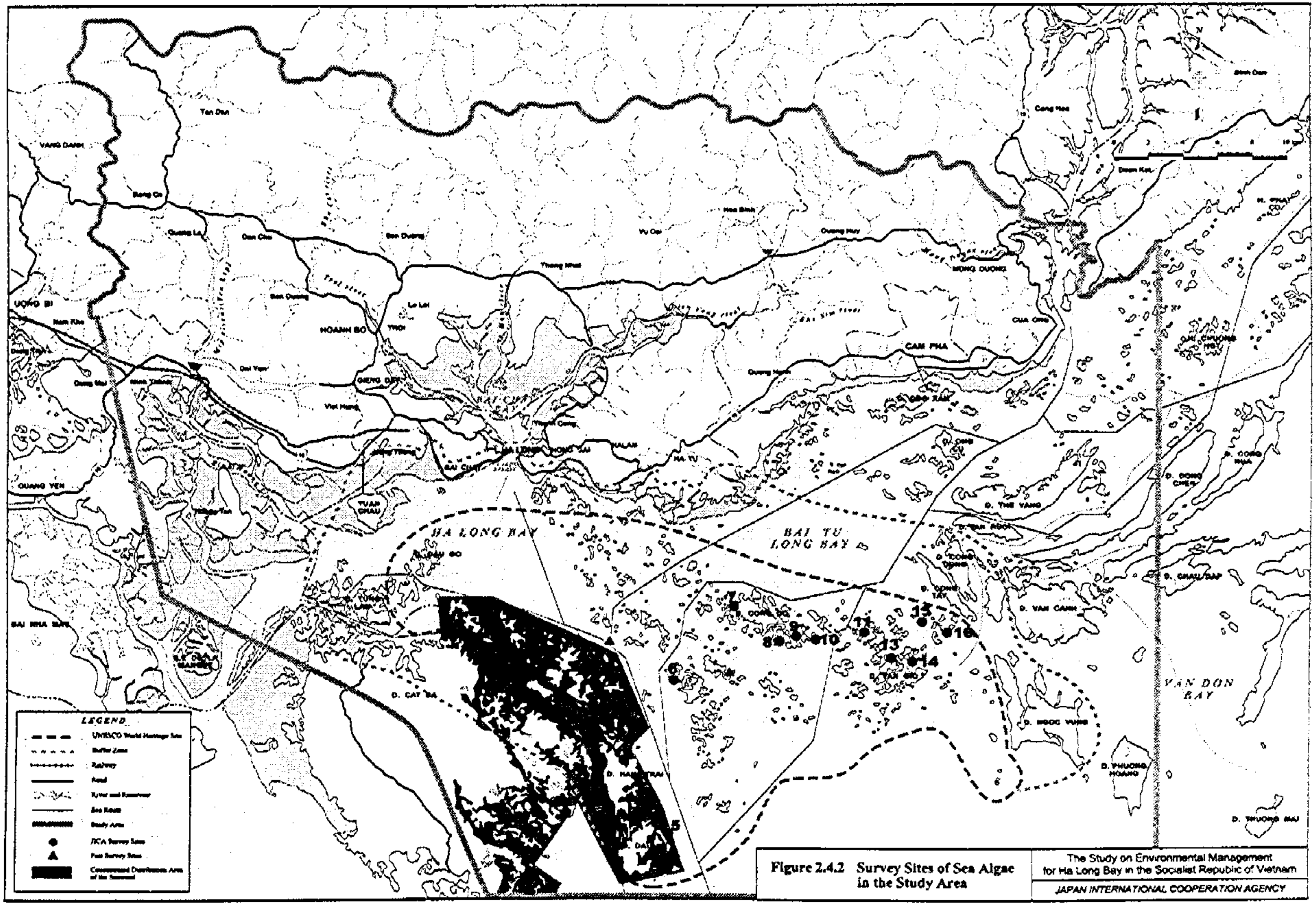

Figure 2.4.2 Survey Sites of Sea Algae in the Study Area

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JAPAN INTERNATIONAL COOPERATION AGENCY

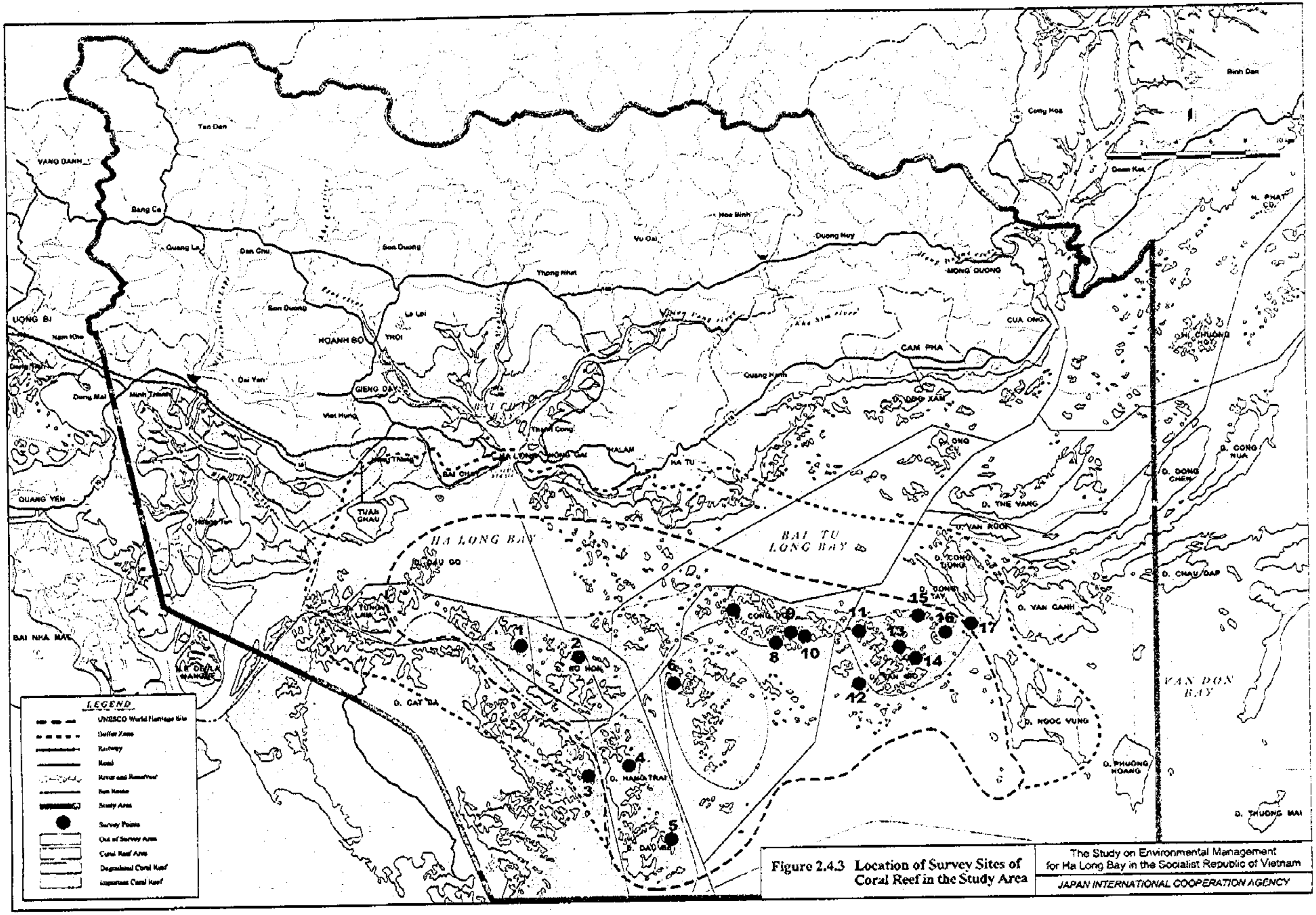

Figure 2.4.3 Location of Survey Sites of Coral Reef in the Study Area

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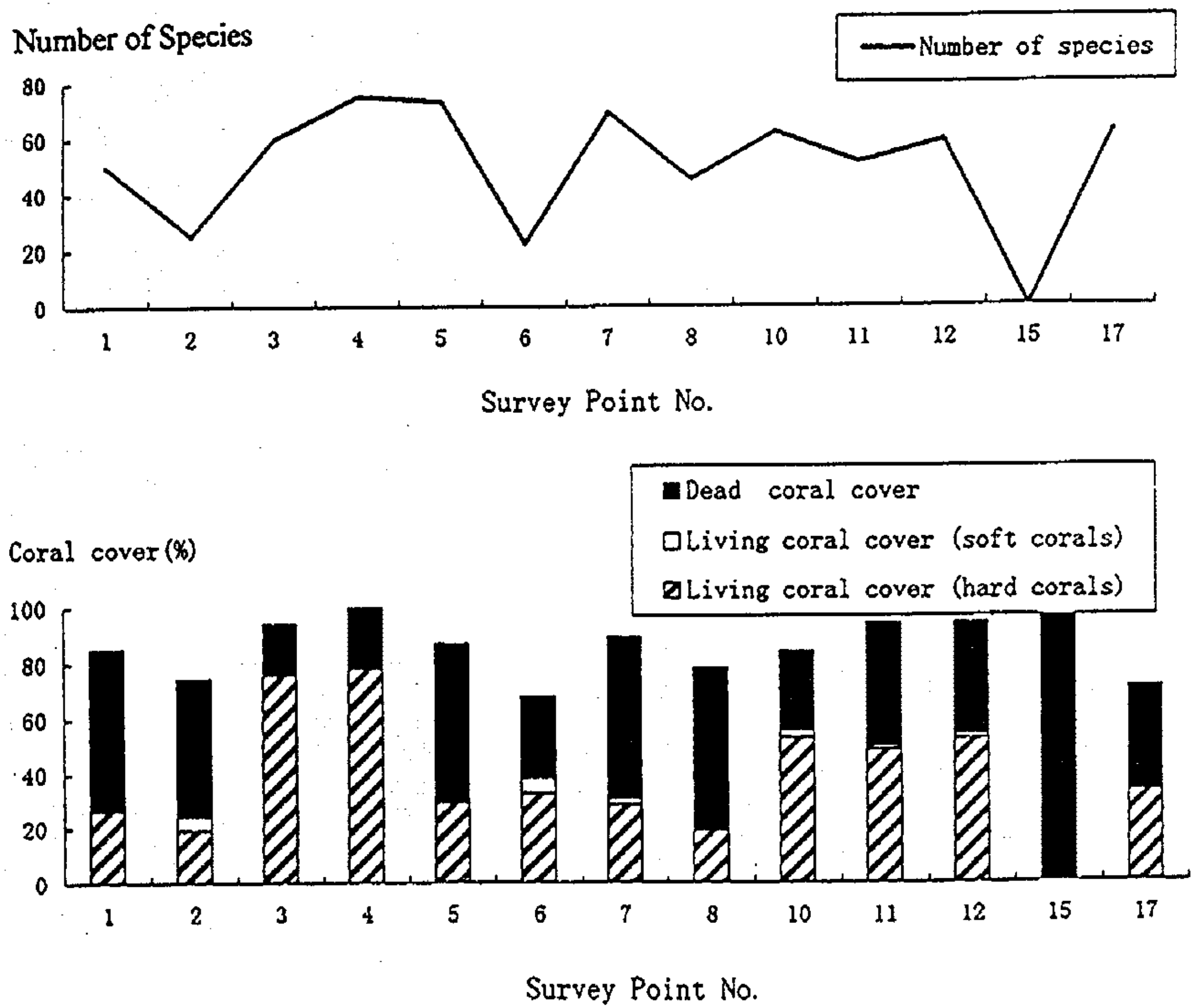
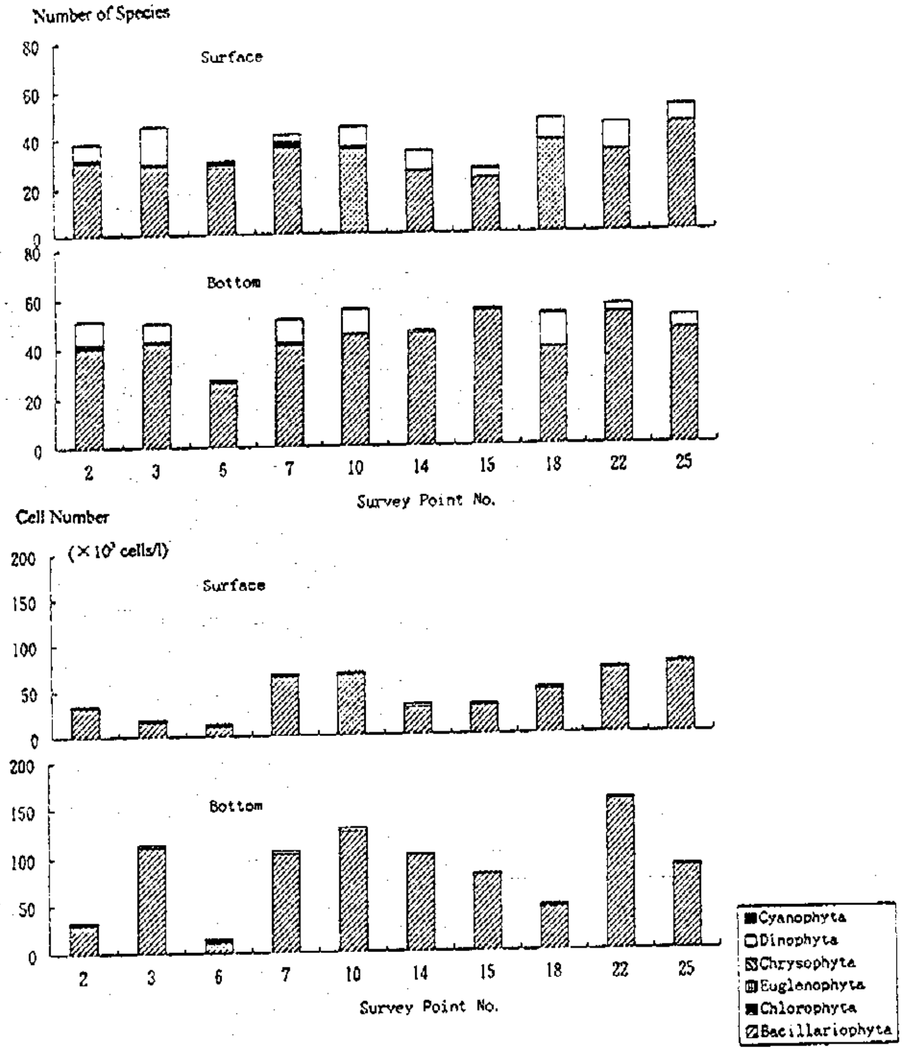


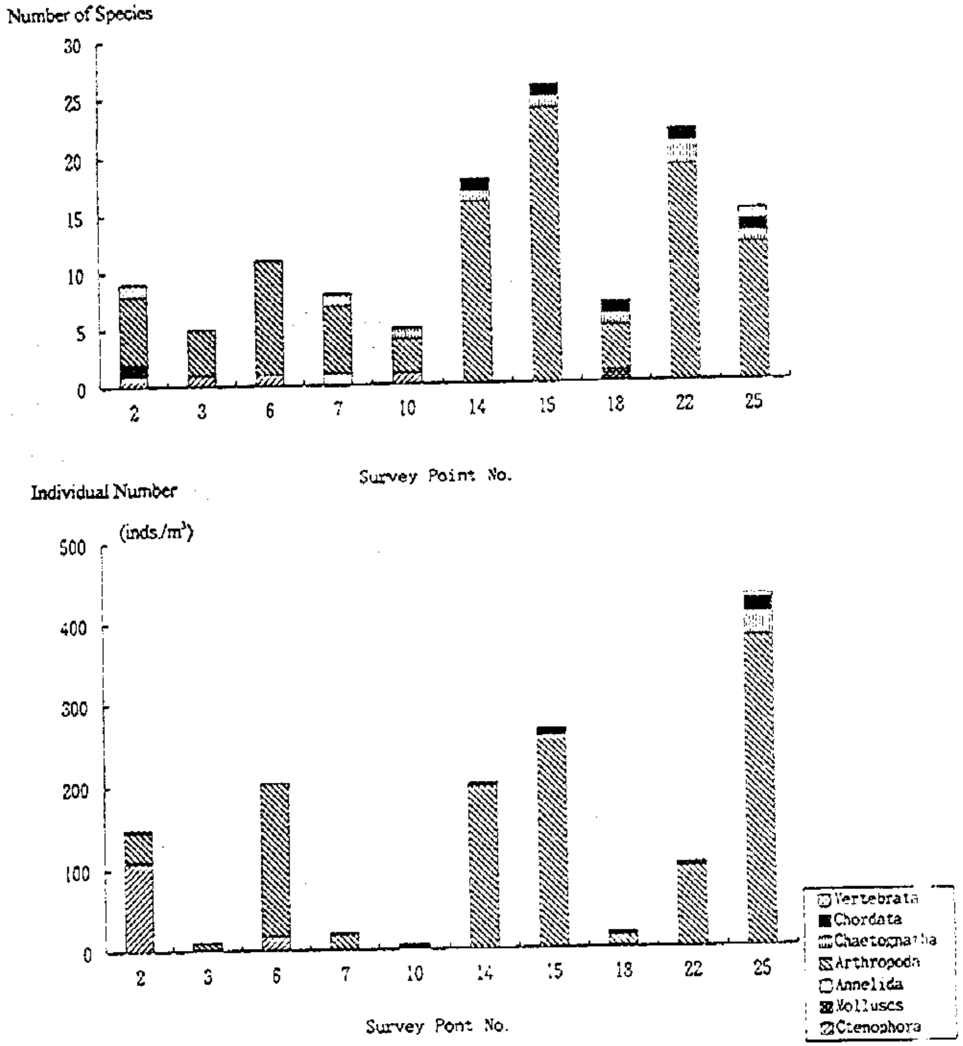
Note: The location of survey point is shown in Figure 2.4.3

Figure 2.4.4 Number of Species and Coral Cover at Each Survey Site in the Study Area



Note: The location of survey points is shown in Figure 5.2.1

Figure 2.4.5 Number of Species and Cell Number of Phytoplankton



Note: The location of survey points is shown in Figure 5.2.1

Figure 2.4.6 Number of Species and Individual Number of Zooplankton

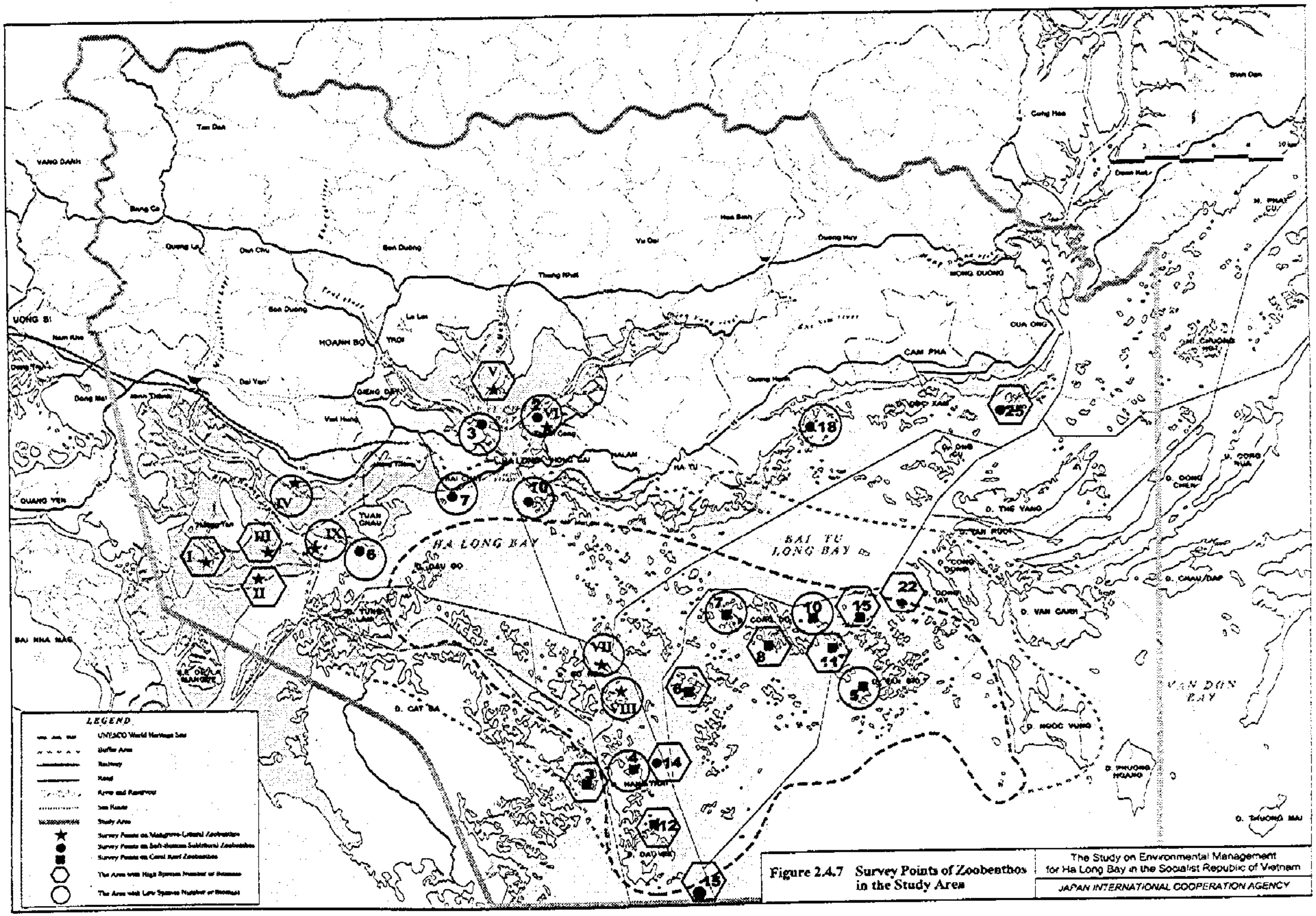


Figure 2.4.7 Survey Points of Zoobenthos in the Study Area

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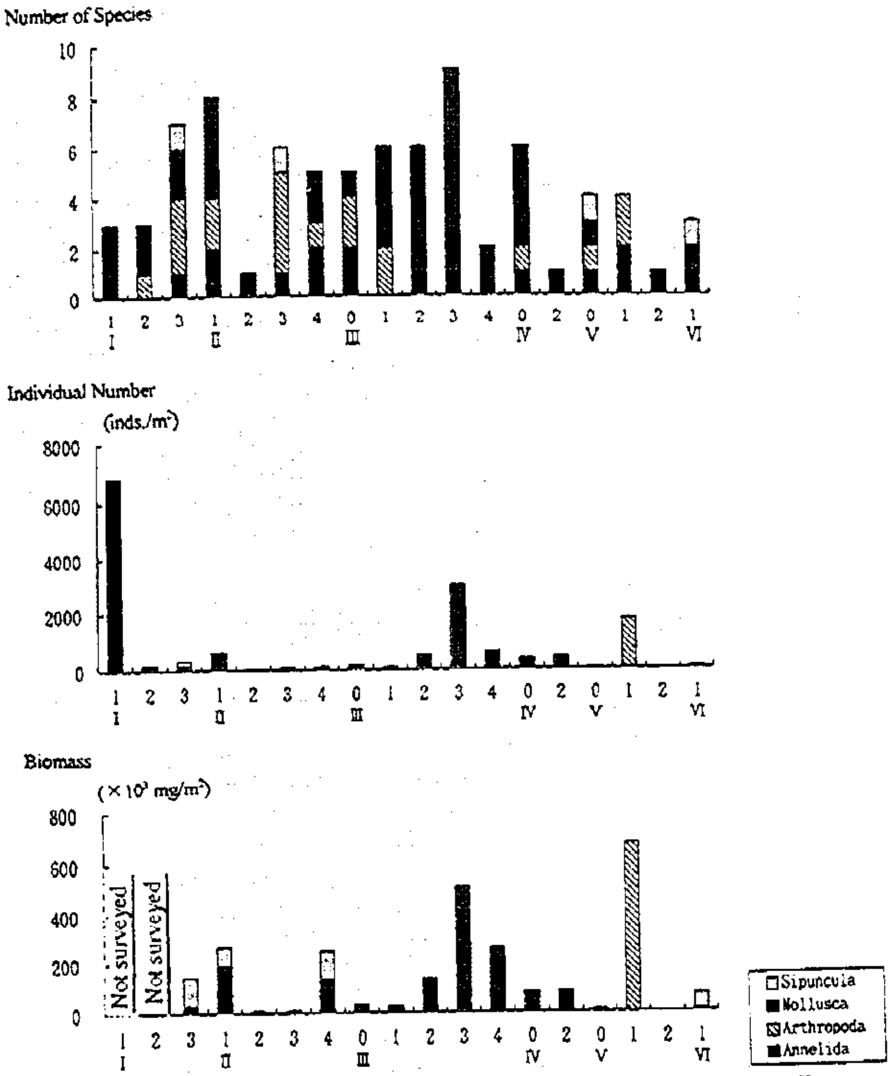
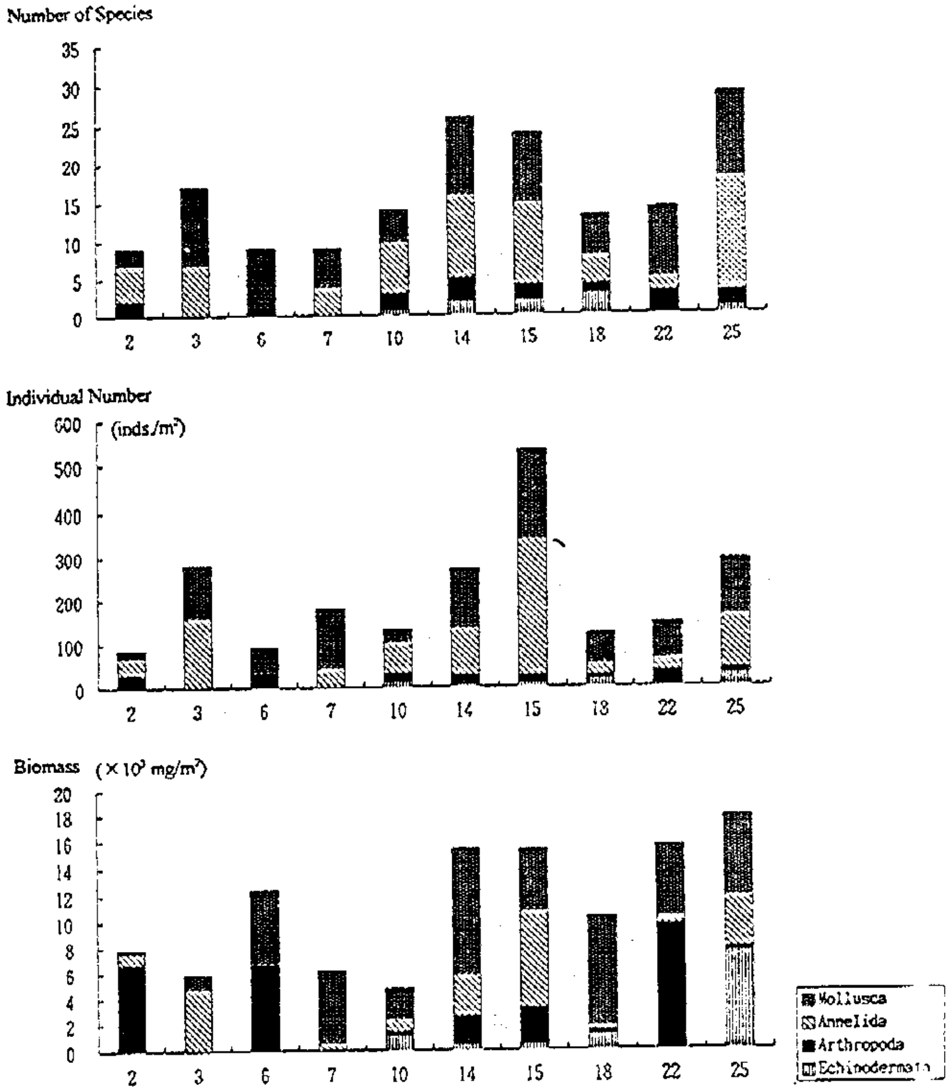


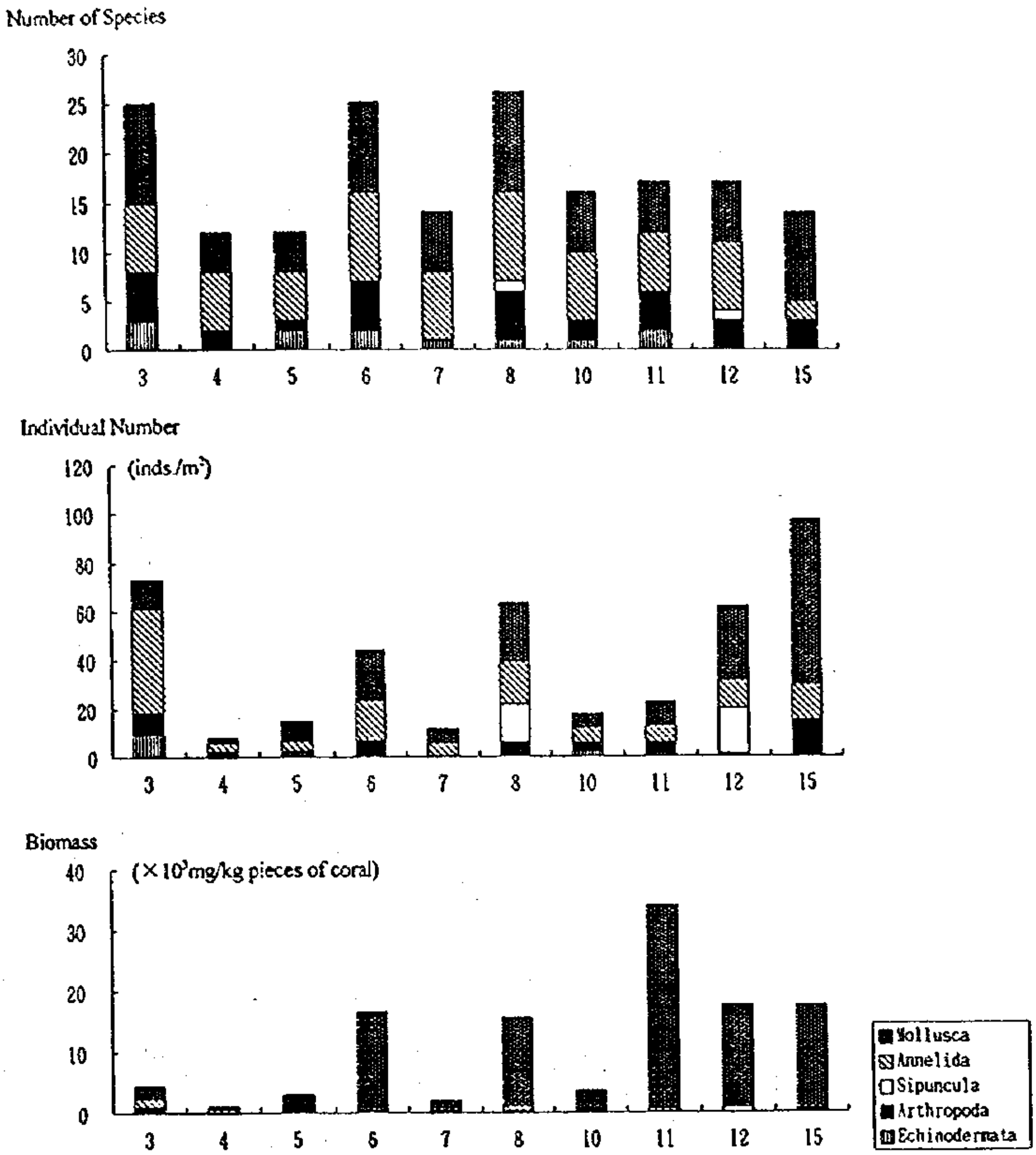
Note: 1. The number of 0-4 shows sampling station No. at each survey point (I-VI).
2. The location of survey points is shown in Figure 5.2.4.

Figure 2.4.8 Number of Species, Individual Number and Biomass of Zoobenthos in Mangrove Swamps



Note: The location of survey points is shown in Figure 5.2.4

Figure 2.4.9 Number of Species, Individual Number and Biomass of Zoobenthos in Sublittoral in the Soft Bottom



Note: The location of survey points is shown in Figure 2.4.7.

Figure 2.4.10 Number of Species, Individual Number and Biomass of Zoobenthos in Coral Reefs

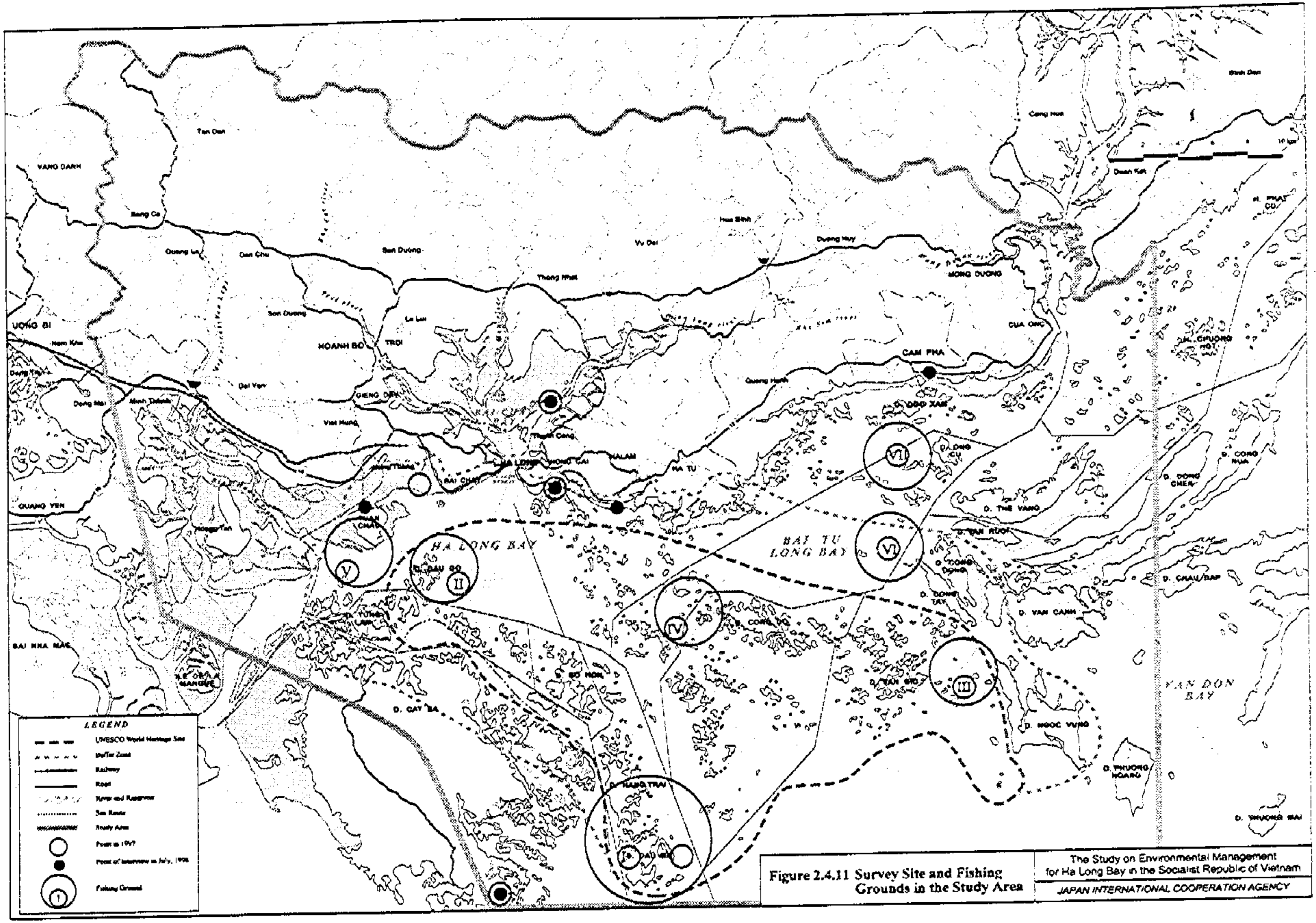


Figure 2.4.11 Survey Site and Fishing Grounds in the Study Area

CHAPTER 3

CHAPTER 3 WATER POLLUTION MECHANISM

3.1 Oceanographic Conditions

3.1.1 Coast and Sea Bed Topography

(1) Geomorphology

Ha Long bay is delimited by the Hong Gai estuary in the north and the outer bay which extends out to Cat Ba island. Bai Tu Long bay is located east of Ha Long bay. The seabed in the bays is relatively flat and shallow, and it is typically only a few meters in depth. The average depth is only 1.0-1.5m adjacent to the coastline, sloping gently (0.001-0.006°), toward the southeast extending 2 m deep on average. However, there are narrow depressions or rivulets in the seabed up to 30 m deep (Lach Van), which allow the large vessels such as coal transport ships and cargo ships to approach the coastline.

The Environment Agency of Japan shows a geometrical index for indicating a closed level of sea area, which is a ratio of water volume of bay and area of bay mouth. Since the index of Bai Chay bay is 4.9, the water body there has a high potential of eutrophication.

(2) Distribution of Tidal Flats

Tidal flat can be defined as an emergence which is submerged in high tide and exposed in ebb tide. The tidal flat in the Ha Long bay area covers the whole Cua Luc embayment with an area of about 210 km^2. An extensive tidal flat being covered by mangrove is found around the estuary of the Mip river with about 9 km^2 and in Bai Chay bay with about 5 km^2. Tidal flat has a water purification function as well as preservation of biodiversity and nursery ground of fishery resources.

Land reclamation works have been carried out in many places along the shoreline, and they change hydrological conditions. According to the result of satellite images analysis in 1988 and 1996, the tidal flat in Bai Chay bay has decreased about 350 ha. In Cam Pha, about 150 ha of tidal flat has been reclaimed by coal mining activities such as solid wastes or coal shipping ports.

The biggest land reclamation so far was carried near Hung Thang for tourism development with about 30 ha. In the future, about 200 ha is planned to be reclaimed. A causeway having two bridges is being constructed between Hung Thang and Tuan Chau island.

3.1.2 Seabed Sediments

The sediment in the bays shows a typical grading shoreline with coarser-grained sediments near shore and finer-grained sediment offshore. Bottom sediments in the bays are dominated by mud, silt, and clay, but those of Bai Chay bay contain sand, gravel and even cobbles as well as organic maters and settled detritus. Sands mainly from pieces of quarts with gravel, cobbles, boulders, and solid wastes (pieces of ceramic, bricks, and bottles) are found in the Bai Chay area. Fine sediments near the Hong Gai, Cam Pha, and Cua Ong coal ports are black in color mainly due to fine coal.

Normally, the critical tractive force of bottom sediment has a close relationship with its water content. Small grain size sediments has a high water content, so they are stirred up easily by turbulence of current. As the results of field reconnaissance and satellite images analysis, high turbidity by tidal activity is found around shipping routes in the shallow water area. This indicate that bottom sediments have relatively high water content.

3.1.3 Tides and Tidal Currents

(1) General Feature of Tides and Tidal Currents

The coastal area of Quang Ninh province has the highest tide in the North Vietnam. In the study area, high water tide occurs once a day for most of the days, occasionally twice a day in a month. Tides have been observed at Hong Gai station. The average tidal amplitude is about 2 m and maximum is 4.7 m in spring tide.

The current tendency was analyzed from temperature distribution portraits based on LANDSAT TM data. As the results of the analysis, it could be concluded that the water body nearshore does not flow out to open sea. That is, the water body in Ha Long bay is stagnant especially in the rainy season. This condition is important for considering the water quality mechanism in the study area.

(2) Field Survey by the JICA Study Team

The current measurement was conducted by the JICA study team in July 1998. The main objective of the measurement was to provide 15-day continuous data series necessary for harmonic analysis at three stations for upper and lower layers. The harmonic constants obtained by the analysis will be used for the validation of the hydrodynamic model through the comparison with the simulated results.

The locations of the stations are shown in Figure 3.1.1.

The output of the data processing included current velocities, running mean currents, current roses, harmonic constants, tidal current ellipses, auto-correlation, power spectra, and diffusion coefficients.

The results are summarized below:

- The velocities of the upper layer were higher than those of the lower layer especially at Cua Luc,
- The long term driving forces such as fresh water from rivers affected the upper layer mainly,
- The tide is the major driving forces for the currents,
- The diurnal constituents such as K_1 and O_1 dominated,
- The current velocities during the spring tide were far higher than those during the neap tide,
- Although the southern wind dominated during the Field Survey, the averaged currents of the upper layer at the Cua Luc strait clearly showed southward direction. These suggested that the freshwater from the rivers to Bai Chay bay would be transported mainly in the upper layer.

(3) Dry Season Field Survey by DOSTE

The current measurement for the dry season was conducted for 24 hours during the spring tide at Cua Luc and Cam Pha – Cua Ong in November 1998. The Cua Dua station was missing from the field survey in the dry season. Only the current velocities, current vectors, and the average velocities were obtained from the data because the measurement period of 24 hours is not enough to conduct harmonic analysis.

The northward component of the velocity dominated in the Cua Luc strait and the eastward component dominated in Cam Pha – Cua Ong. These were the same characteristics as in the rainy season. On the other hand, the velocities of the lower layer at Cua Luc were higher than the velocities in the rainy season.

Although the northern wind dominated at Cua Luc during the survey period, the southward component of the upper layer, 2.7 cm/s was lower than 13.1 cm/s in the rainy season. This suggested that the major cause of the southward currents of the upper layer at Cua Luc was not the wind but the freshwater inflow to Bai Chay bay.

3.1.4 Water Mass Structure

From the drastic change of water color observed during the field reconnaissance, it could be concluded that there is a "tidal front" (tide-rips) in the bays. This means there are two kinds of water bodies confronting each other. The constant current is weak near the tidal front, and water body between coast and tidal front is regarded as a stagnant-water area. This tidal front lies about 15-20 km from the shoreline.

As the result of the Field Survey, relatively lower values of salinity with 12-17 ‰ which indicate the existence of fresh water body are identified in the upper layer of Bai Chay and Ha Long bays. This existence of two kinds of values of salinity indicates that the water in Bai Chay and Ha Long bays is stratified. Considering the distribution of salinity values, the fresh water comes form the catchment area especially through the Cua Luc strait fans out and stays there, and the offshore water creeps wedge-wise into the bays.

The front of salt wedge is so called a "null point" where the constant current in the lower layer is almost zero. Normally, land base pollutants such as SS settles easily around this area. Thus, this stratification characterizes the bays' water quality.

3.1.5 Water Exchange in the Bay

Thus, volumes of water of Bai Chay bay and Ha Long bay are estimated about 6,300 x 10^6 m^3 and 60 x 10^6 m^3, respectively.

Assuming that the exchange of the bays' water is caused only by the river flows and precipitation on the sea, the retention time of the bays' water is about one month for Bai Chay bay, and more than six years for Ha long bay including Bai Tu Long bay as shown below.

Bays	(a) Volume of bay water (x10^6 m^3)	(b) Water inflow (x10^6 m^3/year)	(c) Retention time (a/b)
Bai Chay bay	60	572	0.1
Ha Long and Bai Tu Long bays	6,300	981	6.4

Note: Water inflow includes precipitation on the sea.

3.2 Water and Sediment Quality

3.2.1 Overview of Historic Water Quality Data

Investigations of water and sediment quality of the bays have been dominated by studies conducted since 1992. Approximately 34 water and sediment quality variables have been measured as part of the investigations or projects' studies. However, almost no water quality data exists for the tributaries of the rivers flowing into the bays.

The data suggest that the water quality of Bai Chay bay is different than water quality in outer Ha Long bay near the Cat Ba island. This indicated that the effects of untreated domestic and industrial effluents of Ha Long city were restricted to the nearshore area. Nearshore water quality of the bays falls within the Eutrophic Water Classification (OCDI) or the mesotrophic state which is a typical of coastal estuarine environment (Clark 1996). The influence of land-based pollution on offshore water quality adjacent to Cat Ba island appears to be minimal.

3.2.2 Water Quality of the Rainy Season by the Field Survey

(1) Methods

The Field Survey of water and sediment quality in the bays and the rivers was conducted by HIO during July and August of 1998 under the supervision of the JICA study team. In addition to the surveys, field and laboratory studies were conducted to describe the major mechanisms through which land- and water-based pollution enter and reach equilibrium in the bays.

With regards to water and sediment quality, the Field Survey sampled 38 variables at 30 and 15 sites, respectively, in Bai Chay, Ha Long, and Bai Tu Long bays which included nutrients and heavy metals. A similar set of variables was sampled from 15 sites in the rivers of the study area (Figure 3.2.1, Table 3.2.1).

(2) Water Quality in the Rivers by the Field Survey

SS levels in the Troi and Dien Vong rivers are over the Inland Water Quality Standard in Vietnam (TCVN) during the dry conditions. Similarly the rivers near Cam Pha including the Mong Duong river also exceed TCVN. The high level of SS in some rivers during the dry conditions could be due to soil erosion from deforestation and agricultural activities, or from a runoff associated with coal mining activities.

Nitrate nitrogen, DO, and BOD concentrations in the rivers do not exceed TCVN, and nitrate nitrogen does not exceed the Canadian freshwater standard of approximately 0.6 mg/ℓ. Based on these standards, water quality of the rivers does not impair the aquatic life. The high concentrations of nitrogen in two rivers near Cam Pha (No. 13 and 14) are considered to be due to the influence of mining activities.

High concentrations of iron and zinc in the rivers draining the Hong Gai quarter and the rivers along the coast to Cua Ong coincide with the presence of coal mining activities in these areas. Iron levels in some of these rivers greatly exceed TCVN of 1 mg/ℓ. Zinc levels in one tributary also exceeded the standard of 1 mg/ℓ. These rivers run through some large coal mining areas. The low pH in some rivers is consistent with the effects of mine drainage. Low pH acts to mobilize natural metals from geology that would be occurring from drainage basins in which coal mining occurs.

Some of the high concentrations of iron and zinc measured at inshore stations in the bays could be associated with the rivers that are discharging high concentrations of these metals. The relatively high iron concentrations in Bai Chay bay may be due to discharge from the tributary just north of Hong Gai. Similarly, the relatively high iron levels at inshore bay stations east of Hong Gai to Cua Ong could be associated with iron discharged from tributaries along that shoreline.

Similar to bay nutrient concentrations, the difference between shoreline and offshore iron and zinc levels suggest that the effects of the high tributary concentrations and thus loads of these two metals do not extend far beyond the respective river mouths. There does not appear to be a relationship between metal concentrations in bay sediments and tributaries.

(3) Water Quality in the Bays by the Field Survey

1) DO

DO levels at bottom strata in the nearshore area of the bays often violate standards because concentrations exist below 80% saturation. The decrease in surface DO and the increase in bottom DO, respectively from Bai Chay bay offshore to the Cat Ba island likely reflects the mixing of highly oxygenated freshwater from Bai Chay tributaries with low oxygenated saline bottom waters originating from the Gulf of Tonkin.

Oxygen is a critical water pollution variable because of the requirement of oxygen by aquatic organisms, and because it responds directly to changes in BOD loadings. The marginal levels of oxygen at bottom strata may stress sensitive benthic organisms in the bays, and pelagic fishes that require the bottom for feeding or spawning habitat.

The correlations between shoreline BOD and DO show nicely the link between these two water pollution variables. BOD levels in the bays correspond to the slightly polluted eutrophic water classification of OCDI and to mesotrophic coastal water.

2) Nutrients

The shoreline concentrations and offshore gradients of T-N, NH_4-N, and NO_3-N from Ha Long city and from Cam Pha-Cua Ong suggest that nitrogen that enters the bays from land-based sources is assimilated in the nearshore area resulting in the decay of waterborne nitrogen offshore. Nitrogen concentrations in the bays sediments strongly support the assertion that Ha Long city and Cam Pha-Cua Ong are potentially large sources of nitrogen. The relatively low nitrogen levels in offshore sediments support the hypothesis that nitrogen loads from land-based sources are assimilated and removed from the water column and sediment in the nearshore zone.

The range of chlorophyll-a concentrations throughout the bay exceeds levels expected in offshore oligotrophic waters. For example, the limit for the protection of coral reefs is approximately 0.6 μg/ℓ (Connell and Hawker, 1992).

3) SS

The steep SS gradient offshore suggests that the effects of intensive coal mining activities of Cam Pha and Cua Ong on water quality are restricted to nearshore areas. The relatively low SS levels in Bai Chay bay can be attributed to quiescent conditions.

The historic SS levels, while significantly higher than 1998 data, did not violate TCVN for coastal water. It is the judgment of the study team that the standard for SS of 50 mg/ℓ is too high. A more acceptable standard is the general international standard of 15 mg/ℓ for coastal waters. When 1998 SS levels are compared to this more conservative standard, SS exceeded the standard at 4 stations: these were the Mip river estuary, Bai Chay, and two stations adjacent to Cam Pha.

4) Fecal coliform

Fecal coliform levels measured are consistent with historic levels measured in the bays and show high levels in nearshore waters adjacent to Ha Long city and to a lesser extent Cam Pha and Cua Ong. Fecal coliform levels violate TCVN for water used for drinking, swimming and recreation. Bacteria levels are particularly serious for the development of tourism industry in Bai Chay area. Remedy of coliform will require sewage treatment or relocation of domestic waste discharges.

(4) Water Quality of the Dry Season

1) Nearshore conditions in the dry season of 1998

The surveyed items were tidal current, water quality and plankton in the bays, and dust. The samples were taken among the inshore stations of the rainy season survey implemented by the JICA study team. Most of the same parameters as the rainy season survey were analyzed. As a reference of the analysis of water mass structure and pollution mechanism of the bays, the surveyed data of the dry season were summarized as shown below:

Water Quality in the Bays during Rainy and Dry Seasons, 1998

Variable	Rainy Season (July)	Dry Season (December)
Temperature (°C)	31.7	24.4
Salinity (ppt)	20.7	30.2
DO (mg/ℓ)	5.5	6.2
BOD (mg/ℓ)	1.2	0.5
COD (mg/ℓ)	6.3	2.6
SS (mg/ℓ)	5.0	3.5
Turbidity (FTU)	8.8	1.7
Oil (mg/ℓ)	1.7	0.7
Chlorophyll-a (surface, mg/ℓ)	2.5	1.8
T-N (mg/ℓ)	1.7	1.0
T-P (mg/ℓ)	0.8	0.4
Coliform bacteria (MPN/100ml)	247	10

Source: 1) Rainy season: Field Survey by JICA study team
2) Dry season: DOSTE

Increases in DO and salinity and decreases in SS from rainy to dry conditions are expected.

Decreased nutrient and chlorophyll-a levels in the dry season are mutually consistent with decreased land runoff. Decreased BOD and COD flowing into the bays supports reductions in primary production.

Lower coliform levels are consistent with lower runoff. The concentrations of heavy metals (Cd, Fe, Hg, As, Cu, Pb) in inshore waters are similar in both rainy and dry seasons.

The lower oil levels in the dry season do not support a concentrating effect resulting from decreased freshwater runoff from the basins. Since the major source of oil is believed to be ships and boats on the bays, greater oil levels in the rainy season are not expected.

In addition to the comparison of dry with rainy season conditions, DOSTE also assessed whether water quality differed between flood and ebb tidal conditions. They found that water quality did not differ significantly between the two tide conditions.

2) Offshore conditions in the dry season

To supplement the inshore water quality data collected by DOSTE in December 1998, the JICA study team sampled an inshore-offshore transect of 9 stations in February 1999 extending from Bai Chay bay to southern outskirts Cat Ba island. Seven stations were re-sampled from the Field Survey in July 1998. Two additional stations were added at the southern outskirts of Cat Ba island.

Transparency, salinity, turbidity, COD and BOD levels in the bays from Bai Chay bay to south of Cat Ba island indicate that offshore water quality in the dry season is relatively homogenous and not heavily influenced by freshwater runoff from the basins. Salinity in Bai Chay bay was similar to salinity in offshore areas suggesting little freshwater input from the basins draining to the bay. Transparency increases offshore to a maximum depth at the two stations sampled south of Cat Ba island. Surface turbidity steadily decreased offshore which supports the increase in transparency.

The range in transparency in the bays in July was greater. These data suggest that different water masses may dominate offshore areas in dry and rainy seasons by turns. The southward prevailing current in winter, as opposed to the northward current in summer, reported for western Gulf of Tonkin (Hoi et al. 1995) support this hypothesis.

3.2.3 Bottom Sediment Quality in the Bays

Bottom sediment quality was measured at some of the water quality sampling sites (Figure 3.2.1). T-N concentrations in sediments adjacent to Ha Long city and Cam

Pha town (about 2-3 mg/g) are higher compared to sediments in offshore areas (less than 1 mg/g). T-P levels in sediments are mostly uniform across all sampling sites. There is not a strong trend of COD in sediments in the bays. Arsenic is the only metal that shows regional differences in concentration with the relatively high level measured in Bai Chay bay.

3.2.4 Influence of Offshore Water Body

(1) Existence of Contaminated Water Body

Relatively lower values of salinity with less than 15‰ were measured offshore area during the Field Survey in July 1998. Lower salinity indicated that this water body was originated by fresh water and was different from that in the center of Ha Long bay.

The levels of COD, SS, and nutrients showed an unexpected change, steeply increase along transect of five or more stations from the center of Ha Long bay to offshore. There is a sudden drop of transparency offshore area, too. These changes in water quality were supported by significantly reduced surface salinity at the two southernmost, offshore stations. Thus, it is possible to build up a hypothesis that there is a relatively contaminated water body, which is seemed to be from the large river system.

(2) Potential Influence from Outside of the Study Area

The water body having a relatively higher water temperature was found in the southern outskirts of the study area by the satellite image analysis of water temperature in June 6, 1997. This water body flew from southwest to northeast. Normally the tidal current of the Gulf of Tonkin flows from south to north during the rainy season. Considering the necessity of great amount of fresh water supply with relatively higher water temperature and direction of the tidal current, it seems reasonable to suppose that the origin of this water body would be a large river system in the southern outskirts of the study area.

On the other hand, the tidal current of the Gulf of Tonkin flows from north to south in the dry season. The possibility of influence by the large river system in the dry season is lower than it is in the rainy season.

(3) Wide Range Satellite Image Analysis

The effect of the large river system needs to be investigated further, such as getting a wide range of information from satellite images. The plume from the river system needs to be characterized in terms of both quality and spatial extent.

LANDSAT images of both false color and water temperature covering the estuary of the Red river in June 6, 1997 and in July 11, 1998 reveal that a relatively warm, turbid water mass from the southwest influences the water in Ha Long bay (see Figure 3.2.2 to 5). The northward prevailing currents in western Gulf of Tonkin in rainy season are identified by this wide range LANDSAT images analysis. Discharged contaminated water from the Red river system, especially for the Thai Binh river and the Bach Dang river, flows southern outskirts of Ha Long bay.

3.3 Pollution Source Inventory and Database

The database established for the Study consists of the pollution source inventory, pollution load estimation module, and other sub-database relevant to EMP.

3.3.1 Pollution Source Inventory

(1) Pollution Source Inventory

The pollution source inventory especially for the specific pollution sources, was developed as a part of components of the database. The various data on the land-based specific pollution sources in the EMP area such as factories and coal mines, which was collected by conducting the questionnaire survey by the JICA study team in 1998, was inputted and sorted out in the database. The data on the specific pollution sources was used to estimate pollution load generation from each pollution source. Statistical results of the questionnaire survey, especially focusing on the data related to the pollution load estimation, are shown in Section 10.1.2 of the Supporting Report, Volume III.

(2) Update of the Inventory

The data in the inventory need to be updated timely to grasp the latest pollution load generation from each specific pollution source and each sub-catchment. Regarding to the specific pollution sources, when new facility or any change of existing facility concerned as a pollution source is registered with Quang Ninh province, DOSTE obtains the information on the facility and should revise the inventory. Data on non-specific pollution sources such as land area for agricultural activities are reviewed at least once a year.

3.3.2 Pollution Load Estimation Module

Based on the estimation of the pollution load from specific and non-specific pollution, a pollution load estimation module was integrated into the database by linking with the pollution source inventory. The module is allowed users to get latest pollution load generation in each sub-catchment when the pollution source inventory is updated. Also the estimated pollution load generation from each sub-catchment is checked whether it is satisfied with criteria for each sub-catchment.

The results of the estimated pollution loads of sub-catchment were applied for the water quality simulation model as input data.

3.3.3 Components of the Database

The database consists of four sub-database; a) Pollution Source Inventory Sub-database, b) Water quality Sub-database, c) Natural Environment Sub-database, and d) Regional Socioeconomic Information Sub-database. The Pollution Load Estimation Module was integrated into the Database. The components of the database are shown in Figure 3.3.1.

Various types of data forms were used in the database such as table, graph, map, satellite image, and photo. Users can reach specific data easily by selecting the selective bottom on the menu as shown in Figure 3.3.2. These data can be easily edited, revised, exported, printed out by users since the database software is designed mainly by using basic functions of Microsoft Excel, which DOSTE staff is familiar with.

3.3.4 Updating Data

It is desirable that database be updated in appropriate timing to provide users latest data and information, to accumulate data, and to analyze time-series changes of the data. Relevant to the statistical data such as population, it would be updated periodically when new statistics is issued. On the other hand, some data such as pollution source inventory data should be updated as soon as possible when new facility or any change of existing facility concerned as a pollution source is registered or informed. It is recommended that at least one person who is in charge of the database be assigned to update timely and secure the database. Also one computer should be assigned to keep original database with the latest (updated) data.

3.4 Estimation of Pollution Load Generation

3.4.1 Setting Sub-catchment

The catchment of the bays is divided into 14 sub-catchments for pollution loads estimation and analysis. The sub-catchments accompanied with the main rivers (No.1, 4 to 6, and 14) are located in the northern part of the catchment from the east to the west. The others (No.2, 3, 8 to 13) are located on the littoral areas of the bays, whose gradient varies from 12 to 20%. With regard to islands, Cat Ba island is designated sub-catchment 15 and the other islands are grouped as sub-catchment 16 for the sake of convenience. The land use pattern of each sub-catchment, which was analyzed by satellite image and is the basis for estimating fresh water runoff and non-specific pollution generation, is shown in Table 3.4.1. The location of each sub-catchment is shown in Figure 3.4.1. The estimated amount of freshwater inflow into the bays during the rainy season, from June to August, is shown in Table 3.4.2.

3.4.2 Pollution Sources

For estimation of pollution load, specific pollution sources in the study area are largely classified into three groups namely; domestic wastewater including tourism, industrial wastewater, and livestock wastewater based on the types and/or activities. In case of wastewater from coal mining activities, it is categorized as industrial wastewater for the sake of convenience.

Non-specific pollution sources are diffuse pollution sources which can not be identified site by site. Most loads from non-specific pollution sources are washed out on rainy days. Normally non-specific pollution sources are classified into two groups, land runoff and precipitation. Land runoff in the study area consists of pollution loads from forests, agricultural area, deforested bare area including denuded area by coal mining, and urban area.

3.4.3 Calculation Method of Pollution Load Flowing into the Bays

There are mainly two pathways of pollutants into the bays, via rivers or drains and directly into the bays. Pollution loads via rivers are estimated by one of the two methods depending on the availability of the rivers' water quality data. Parameters required such as run-off ratios are set based on the result of the Field Survey.

For estimation of pollution loads, four major pollution sources such as domestic including tourism, industrial, livestock, and land runoff are selected. The pollution loads from solid waste disposal sites and precipitation are negligible small compared with five major pollution sources. Selected items for the pollution load estimation are BOD, COD_{Mn}, SS, T-N, and T-P.

3.4.4 Estimation of Pollution Load Generation

(1) Specific Pollution Sources

1) Domestic pollution sources

a) Residence

The generated loads of domestic origin are estimated by population and pollution load units. Population multiplied by pollution load unit is generated pollution loads. The per capita pollution load unit of BOD is assumed at 50 g/day based on the results of Water Supply and Sanitation Feasibility Study, 1998. These units were quoted from "Assessment of Sources of Air, Water, and Land Pollution, WHO, 1993".

Pollution load units of COD_{Mn}, SS, T-N, and T-P are taken from "the Guideline for comprehensive basin-wide planning of sewerage systems, Japan Sewage Association, 1996 (the guideline)", and modified by the JICA study team.

The population in the study area was about 341,000 in 1996. The total generated loads of domestic origin amount to 17 tons/day of BOD, 7.5 tons/day of COD_{Mn}, 13 tons/day of SS, 3 tons/day of T-N, and 0.4 tons/day of T-P.

b) Tourism

Pollution loads generated from tourism are classified into three categories namely tourists in hotels, day's tourist, and tourist boat. The mean residence time of tourists in hotel is assumed to be about 19 hrs. The maximum number of tourist boats in Ha Long bay is 150 (HLMB). Assuming one boat carries 10 passengers, the maximum number of passengers on the boats a day is 1,500. It is assumed that mean cruising time of the passengers on the boats is 8 hrs.

The pollution load unit of tourist is changed in proportion to their residence time. Thus, the per capita pollution load unit of tourist in hotels is 80% and passenger on tourist boats is 30% of domestic one, respectively.

The estimated total generated pollution loads are 0.05 tons/day of BOD, 0.02 tons/day of COD_{Mn}, 0.04 tons/day of SS, 0.01 tons/day of T-N, and 0.001 tons/day of T-P.

2) Industrial sources

The volume of wastewater being discharged from each factory is set based on the result of the questionnaire survey, but the water quality data of the wastewater are not available. Thus, water quality is set by the results of Field Survey and typical water quality of each type of factory taken from the Guideline.

The estimated total pollution loads generated from 57 factories are 0.5 tons/day of BOD, 2.1 tons/day of COD_{Mn}, 25 tons/day of SS, 0.6 tons/day of T-N, and 0.02 tons/day of T-P.

3) Livestock sources

The generated loads of livestock origin are estimated by number of livestock and pollution load units. The number of livestock is estimated by livestock population density taken from data of DARD, and areas of each sub-catchment. The per head pollution load units are quoted from the Guideline. The units of buffalo are assumed to be same as cattle's.

The total numbers of livestock in the Ha Long bay area are estimated at about 4,300 heads of buffalo and cattle, and 63,000 heads of pig. The resulting total pollution loads of livestock origin amounts to 15.3 tons/day of BOD, 10.4 tons/day of COD_{Mn}, 57 tons/day of SS, 3.8 tons/day of T-N, and 1.8 tons/day of T-P.

(2) Non-Specific Pollution Loads

The generated pollution loads of land runoff origin are estimated by area of each land use and pollution load units. The per area pollution load units of BOD, COD_{Mn}, T-N, and T-P are taken from the Guideline, that of SS is taken from "The study on the reddish soil pollution in Okinawa island in Japan, Okinawa general bureau". Regarding SS, pollution load unit of coal mining activities is assumed to be 3,000 $kg/km^2/day$ based on the mass balance at the river mouth.

The areas of each land use pattern in the study area are set at 170 km^2 of agricultural fields, 680 km^2 of forest, 90 km^2 of urban, and 80 km^2 of coal mining areas (see Table 11.6.9), based on the result of satellite image analysis. Total generated loads of land runoff origin amounts to 16 tons/day of BOD, 23 tons/day of COD_{Mn}, 540 tons/day of SS, 14 tons/day of T-N, and 5 tons/day of T-P.

(3) Total Generated Pollution Loads

Total generated pollution load is tabulated in Table 3.4.3. Among the pollution sources, pollution load generated at non-specific pollution sources is largest.

3.5 Runoff Pollution Load into the Bays

3.5.1 Setting Runoff Ratios

The analysis of pollution mechanisms requires data related to type and volume of pollutants being discharged from each sub-catchment into the bays. The pollution loads flowing into the bays are calculated based on the generated pollution loads and run-off ratio. Runoff ratio is a percentage of entering pollution load into the bays to generated pollution load. Runoff ratios depend on land use, type of pollution sources, distance between location of sources and the bays, and intensity of rainfall.

In order to estimate the run-off ratios for the sub-catchments having major rivers, calibration with the water quality data taken by the Field Survey and estimated runoff pollution loads was performed. As for the small coastal sub-catchments, generated pollution loads flow into the bays directly or via short streams. Therefore, the runoff ratios are relatively high compared with that of sub-catchment having the major rivers. Estimated runoff ratios are shown in Table 3.5.1.

3.5.2 Runoff Pollution Loads

Generated pollution loads multiplied by runoff ratio is runoff pollution load. The estimated runoff pollution loads of BOD, COD_{Mn}, SS, T-N and T-P from each sub-catchment are shown in Table 3.5.2 and summarized below. Among the inflow of pollution loads of BOD, domestic pollution loads accounts for about 50% of the total.

Pollution Loads Inflow into the Bays

(Unit: tons/day)

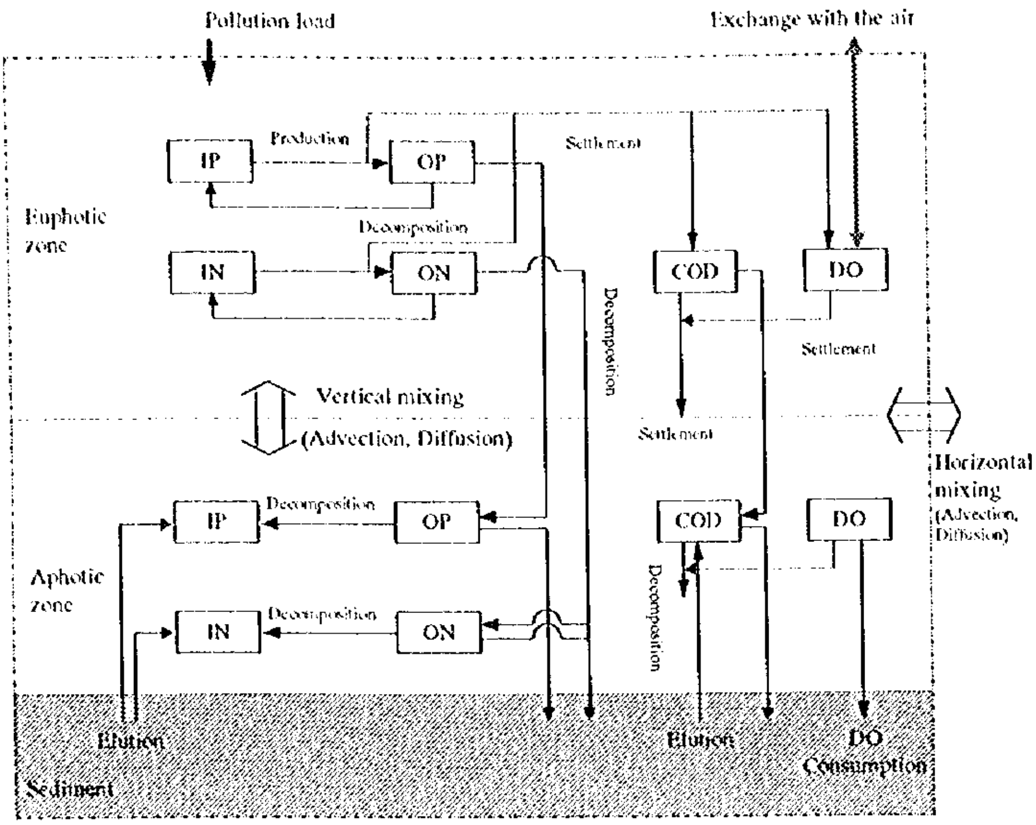
Items	Domestic	Industry	Livestock	Non-specific	Total
BOD	3.0	0.3	1.9	1.9	7.2
COD_{Mn}	4.9	1.9	2.8	12.3	21.9
SS	8.5	22.1	16.3	194.0	241.1
T-N	2.7	0.5	2.5	9.7	15.5
T-P	0.3	0.02	1.5	4.2	6.1

Note: Domestic pollution load includes that of tourism.

3.6 Rates of Primary Production, Decomposition, Settlement, and Elution

3.6.1 Expected Pollution Mechanism in the Bays

The pollutants that enter the bays are subjected to various physical, chemical, and biological processes. The study of physical and chemical behavior of pollutants flowing into the bays, and their material circulation are required in order to clarify a pollution mechanism in the bays. Normally, organic pollutants produced by primary production of phytoplankton is one of the key contributors of organic pollution in the stagnant water. Besides, pollutants such as COD, inorganic nitrogen (I-N) and inorganic phosphorus (I-P) are released from the cumulated pollutants in the bottom sediment. On the other hand, decomposition and settlement of pollutants acts on purification of the water. The expected mechanism of water pollution in the bays is as shown below:



Note: IP: Inorganic phosphorus OP: Organic phosphorus
IN: Inorganic nitrogen ON: Organic nitrogen

Figure 3.6.1 Expected Mechanism of Water Pollution in the Bays

3.6.2 Field Survey for the Pollution Mechanism Parameters

(1) Methods

In order to grasp the pollution mechanism parameters of the bays, the following tests consisting of productivity, decomposition, settlement, and elution tests (the Tests) were implemented in the course of the Field Survey. The Tests were carried out at five points in the bays. Items and methods of the Tests are as follows:

Items	Subjects	Methods
Productivity test	Primary production rate by phytoplankton	Light and Dark (LD) bottle method *in situ*
Decomposition test	Decomposition rate of organic matters	Dark bottle method in laboratory
Settlement test	Settling velocity/flux of organic particles	Settlement sampler method *in situ*
Elution test	Release rate from bottom sediment	Experimental water tank method in laboratory

(2) Results of the Tests

1) Productivity rate

Net production ratio (Pn) is obtained by the light bottle test and amount of respiration (R) is from the dark bottle test. Gross production (Pg) is sum of Pn and R. Obtained data by the LD bottle tests and the amount of primary production in terms of COD_{Mn} in the bays are estimated as shown below:

Location	Layer	Gross Production	Primary Production	
		(O_2mg/ℓ/h)	(mg C/m³/h)	(COD_{Mn} mg/m³/h)
No. 2 Bai Chay bay	upper lower	0.737 0.196	276 74	426 113
No. 6 West of Ha Long bay	upper lower	0.493 0.134	185 50	285 78
No. 13 Center of Ha Long bay	upper lower	0.112 0.047	42 18	65 27
No. 22 Center of Bai Tu Long bay	upper lower	0.176 0.139	66 52	102 80
No. 25 East of Bai Tu Long bay	upper lower	0.114 0.116	43 43	66 67

2) Decomposition rate

Based on the observed data by the decomposition tests, polygonal graphs are drawn by method of least squares between concentration of each item on the horizontal line and time series of test on the vertical line. Decomposition rates are gradients of graphs and summarized as shown below:

Location	Layer	COD_{Mn} (1/day)	O-N (1/day)	O-P (1/day)
No. 2 Bai Chay bay	upper lower	0.1199 0.1182	0.0154 0.0189	0.0025 0.0025
No. 6 West of Ha Long bay	upper lower	0.0787 0.0875	0.0174 0.0216	0.0037 0.0032
No. 13 Center of Ha Long bay	upper lower	0.0841 0.0954	0.0077 0.0098	na na
No. 22 Center of Bai Tu Long bay	upper lower	0.0466 0.0756	0.0052 0.0093	0.0014 0.0024
No. 25 East of Bai Tu Long bay	upper lower	0.1833 0.2706	0.0065 0.0096	0.0040 0.0029

Note: na means not available.

3) Settlement rate

Based on the observed data by the settlement tests, flux of settling matters per unit area was calculated. Settlement rates are summarized below:

Location	Layer	COD_{Mn} (m/day)	O-N (m/day)	O-P (m/day)
No. 2	upper	0.7	2.1	0.1
Bai Chay bay	lower	1.3	2.1	0.2
No. 13	upper	0.7	0.9	0.4
West of Ha Long bay	lower	0.9	0.9	0.4
No. 13	upper	1.1	1.7	1.4
Center of Ha Long bay	lower	2.9	3.1	1.7
No. 22	upper	1.9	2.2	0.4
Center of Bai Tu Long bay	lower	4.7	5.3	0.3
No. 25	upper	3.7	3.2	0.8
East of Bai Tu Long bay	lower	4.8	5.3	0.8

4) Release rate

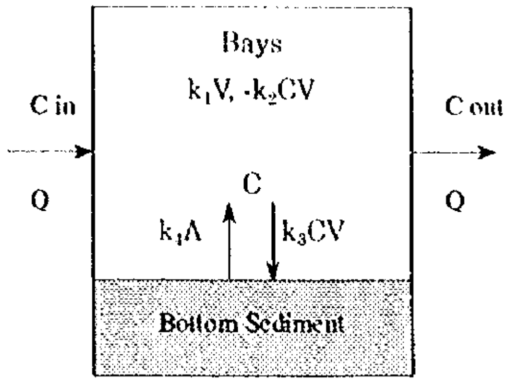
Based on the obtained data, amount of released matters per square meter in the water and amounts of dissolved matters in the water in experimental tanks were calculated. Polygonal graphs are drawn by least squares methods, plotting amount of matters in the water per area in the experimental tank on vertical line and time series of test on horizontal line. Release rates are gradient of graph, and summarized as shown below:

Location		COD_{Mn} ($mg/m^2/day$)	I-N ($mg/m^2/day$)	I-P ($mg/m^2/day$)
No. 3	Bai Chay bay	93.7	10.2	2.1
No. 6	West of Ha Long bay	56.3	13.6	1.6
No. 14	Center of Ha Long bay	49.7	10.8	2.6
No. 22	Center of Bai Tu Long bay	55.2	14.9	3.6
No. 25	East of Bai Tu Long bay	149.2	12.6	1.6

3.7 Mass Balance of Pollutants in the Bays

3.7.1 Methods of Mass Balance in the Bays

Material circulation in the bays should be taken into consideration for the analysis of organic pollution mechanism in the bays. The basic concept of mass balance for pollutants in the bays can be schematized as follows:



$$L = QCin - QCout + k_1V - k_2CV - k_3C + k_4A$$

where, C : Concentration of pollutants in the bays (kg/m^3)

Cin : Concentration of pollutants in the inflow (kg/m^3)

Cout : Concentration of pollutants in the outflow (kg/m^3)

k_1 : Primary production rate ($kg/m^3/day$)

k_2 : Decomposition rate (1/day)

k_3 : Settlement rate (m/day)

k_4 : Release rate ($kg/m^2/day$)

V : Volume of water in the bays

A : Area of bottom sediment in the bays (m^2)

Q : Flow rate (m^3/day)

L : Total pollutants in the bays (kg), given by V × C

For the mass balance of pollution loads in the bays, four representative calculation areas are set, namely, Bai Chay bay, Bai Chay and Hong Gai, Cam Pha and Cua Ong, and Ha Long bay including Bai Tu Long bay.

The box mixing method is used for mass balance calculation. This method assumes that once pollution loads flow into each area, i.e., water column, the water and pollutants in each water column are mixed within one tidal period (assumed 24 hours), and pollution loads in the area is conveyed to the outside with same water volume as inflow. The model calculates the balance of pollution loads in each area and seeks a concentration level where area and out flow are equal. In order to simplify the calculation, exchange of water between outside of each area is not considered.

The parameters like primary production, release, settlement, and decomposition rates are set based on the results of the Tests. BOD is used as a representative indicator of pollutants.

3.7.2 Mass Balance of Pollutants

The results of the mass balance calculation of BOD for the present condition (1996) of the bays are summarized below. Standing stock in the table means BOD left in each water column. Based on the results of this mass balance analysis, it seems reasonable to conclude that the organic pollutants represented by BOD in the bays is mainly generated by primary production.

Mass Balance of Pollutants

(Unit: BOD tons/day)

Areas	Contribute increase in pollutants			Contribute decrease in pollutants		Standing Stock
	Pollution Load Inflow	Primary Production	Elution	Self-purification	Outflow	
Bai Chay bay	2.9	45.3	0.6	42.4	6.3	0.1
Bai Chay and Hong Gai	7.6	62.3	0.6	65.0	5.3	0.2
Cam Pha and Cua Ong	2.0	1,234.2	21.3	1,255.1	1.1	1.3
Ha Long bay	10.3	2,004.2	13.5	2,009.7	10.7	7.6

Notes: 1) Self-purification includes decomposition and settlement.
2) Pollution load inflow in Bai Chay and Hong Gai area includes that from the Cua Luc strait.

3.8 Overall Consideration of Water Pollution Mechanism

3.8.1 General Conditions of Water Quality in the Study Area

The results of the Field Survey indicate that the bays' water, on the whole, have mesotrophic condition and little deterioration. However, the water and sediment quality inshore along Ha Long city and Cam Pha-Cua Ong areas are comparatively influenced by land-based effluent discharges. It is obvious that polluted water run-off from the catchment is limited to the inshore areas close to untreated effluent discharge points. The only pollution variable that appears to influence offshore areas is oil mainly due to the presence of shipping activities throughout the bays.

SS and iron are the only problematic variables in some rivers. The rivers experience high SS loads, which is likely a result of erosion from past and present denuded areas by urbanization, coal mining, and agricultural activities. The relatively higher iron levels in some tributaries are likely caused by mine waste in concert with low pH.

The concentrations of heavy metals in water and sediment of the bays are consistent with levels reported in previous studies. The only metals that violate coastal water and sediment quality standards are zinc and cadmium, respectively. The uniform distribution of cadmium concentrations throughout bay sediment suggests that the cadmium concentrations are considered to be natural.

3.8.2 Water Quality Distribution in the Bays

(1) Distribution in Rainy Season

As observed in the Field Survey in July 1998, land-based fresh water together with pollutants is stagnated inshore from the Cua Luc strait to Ha Long bay. Besides, the water in the bays is stratified wedge-wise by land-based fresh water and intruded offshore water which shows relatively higher values of COD, SS, and nutrients than that in the center of the Ha Long bay.

Observed water quality distribution in the dry season is consistent with this water mass structure. Namely, relatively higher values of pollutants are observed inshore and offshore, while lower values in the middle of Ha Long bay. Some parameters such as SS are highest at the front of salt wedge, null point, where run-off pollutants tend to be settled.

(2) Distribution in Dry Season

Observed water quality distribution in the dry season was a little different from that in the rainy season. Salinity in the dry season was higher than in the rainy season due to little precipitation. Stratified water in the rainy season disappeared in the dry season, so that offshore water intruded into the inner part of bays. Accordingly, little differences of the water quality such as transparency was observed throughout the bays in the dry season.

3.8.3 Water Quality in Rainy and Dry Seasons

The observed bays' water quality parameters of BOD, COD, and SS around twice as high during the rainy season than the dry season. Transparency in the rainy season also around half of that in the dry season.

One possibility is that land based pollution loads into the bays in the rainy season are higher than in the dry season. This is mainly due to a high percentage of the pollutants washed out to the bays by the higher rainfall.

Another possibility is an effect of higher primary production. Chlorophyll-a values which show degree of photosynthetic activity of phytoplankton, are around twice as high in the rainy season than in the dry season. This means that photosynthetic rate, namely generated organic matters by primary production, in the rainy season is higher than in the dry season. This relatively active primary production in the rainy season could be caused by the higher land based nutrients washed out by the precipitation, light intensity, and water temperature compared with the dry season.

The productivity rate in the dry season can be obtained from the previous survey by HO, in January 1997. According to this survey, the productivity rate in the dry season is 6 $mgC/m^3/hr$. The rates in rainy season obtained by the Field Survey in July 1998 are higher than that in the dry season, with 43~276 $mgC/m^3/hr$. These data supports possibility of effect of high primary production.

3.8.4 Primary Production in the Bays

As the results of the Field Survey and mass balance analysis, it was found that the primary production by phytoplankton in the bays is active, so that more than half of organic pollution loads is being produced in the bays in the rainy season. This is also indicated by the observed multiplication of phytoplankton such as green algae (*Chlorophyceae*), diatoms (*Bacillariophtcea*) in the bays especially near coast area. Normally, active primary production is induced by inflow of excessive nutrients such as phosphates and nitrogen which encourage growth plankton and alga. The exceeding eutrophication causes decrease in transparency, too. Thus, transparency in the bays is relatively low with 0.5-3 m.

TABLES

Table 3.2.1 Water and Sediment Variables Measured in the Field Survey

Water Quality Variables		
Temperature	Chemical oxygen demand (COD_{Cr})*	Cyanide (CN)
pH	Chemical oxygen demand (COD_{Mn})	Copper (Cu)
Salinity	Biochemical oxygen demand (BOD)	Lead (Pb)
Dissolved oxygen (DO)	Oil	Zinc (Zn)
Turbidity	Chlorophyll-a*	Cadmium (Cd)
Suspended solids (SS)	Total coliform	Nickel (Ni)
Total dissolved solids (TDS)	Fecal coliform**	Chromium (Cr)
Nitrate nitrogen (NO_3-N)	Manganese (Mn)	Manganese (Mn)
Nitrite nitrogen (NO_2-N)	Phosphate (PO_4-P)	Iron (Fe)
Ammonia nitrogen (NH_4-N)	Total phosphorous (T-P)	Transparency**
Total nitrogen (T-N)	Mercury (Hg)	
Bottom Sediment Quality Variables		
Temperature	Ignition loss (IL)	Arsenic (As)
Composition	Chemical oxygen demand (COD)	Manganese (Mn)
Color	Total organic carbon (TOC)	Mercury (Hg)
Mixed matter	Total nitrogen (T-N)	Zinc (Zn)
Water content	Total phosphorous (T-P)	Chromium (Cr)
pH	Hydrogen sulphide (H_2S)	Cadmium (Cd)
Oxidation-reduction potenial (ORP)	Lead (Pb)	

Note: * only in rivers ** only in bays

Table 3.4.1 Land Use at each Sub-Catchment as of 1996

No.	Sub-catchment	Items	Natural Forest	Secondary Forest	Trees on the Limestone	Scrub Land	Grass Land	Agricultural Land	Bare Land	Coal Mining	Urban Area	Water in Land	Total
1	Mip river basin	area (ha)	2,478	12,063	46	2,278	1,400	1,965	182	41	846	4,110	25,409
		ratio (%)	10	47	0	9	6	8	1	0	3	16	100
2	Hung Thang basin	area (ha)	0	10	0	680	27	24	4	0	14	48	807
		ratio (%)	0	1	0	84	3	3	1	0	2	6	100
3	Bai Chay basin	area (ha)	0	9	0	364	7	0	8	0	163	19	569
		ratio (%)	0	2	0	64	1	0	1	0	29	3	100
4	Troi river basin	area (ha)	2,245	8,988	138	3,621	1,222	1,789	285	14	380	994	19,675
		ratio (%)	11	46	1	18	6	9	1	0	2	5	100
5	Man river basin	area (ha)	3,557	3,467	698	890	1,205	987	15	0	216	933	11,967
		ratio (%)	30	29	6	7	10	8	0	0	2	8	100
6	Dien Vong river basin	area (ha)	5,351	8,882	697	4,227	1,734	1,004	82	1,709	152	1,228	25,066
		ratio (%)	21	35	3	17	7	4	0	7	1	5	100
7	Hong Gai north basin	area (ha)	0	4	0	641	115	89	32	195	191	43	1,311
		ratio (%)	0	0	0	49	9	7	2	15	15	3	100
8	Hong Gai south basin	area (ha)	0	4	49	198	50	6	18	3	381	0	709
		ratio (%)	0	1	7	28	7	1	3	0	54	0	100
9	Ha Tu basin	area (ha)	0	85	835	675	181	169	22	790	94	51	2,901
		ratio (%)	0	3	29	23	6	6	1	27	3	2	100
10	Cam Pha west basin	area (ha)	0	263	1,936	305	133	80	51	65	275	30	3,137
		ratio (%)	0	8	62	10	4	3	2	2	9	1	100
11	Cam Pha central basin	area (ha)	0	12	0	335	93	49	40	376	583	36	1,523
		ratio (%)	0	1	0	22	6	3	3	25	38	2	100
12	Cam Pha east basin	area (ha)	0	156	0	235	48	31	38	213	377	7	1,103
		ratio (%)	0	14	0	21	4	3	3	19	34	1	100
13	Cua Ong basin	area (ha)	0	195	0	381	67	0	2	138	89	4	876
		ratio (%)	0	22	0	44	8	0	0	16	10	0	100
14	Mong Duong basin	area (ha)	764	2,947	0	1,736	682	0	41	1,876	33	99	8,179
		ratio (%)	9	36	0	21	8	0	1	23	0	1	100
15	Cat Ba island	area (ha)	3	0	12,257	133	250	287	1	0	32	0	12,964
		ratio (%)	0	0	95	1	2	2	0	0	0	0	100
16	Other islands	area (ha)	2,582	768	3,108	1,143	356	182	8	0	23	0	8,171
		ratio (%)	32		38	14	4	2	0	0	0	0	100
Total (except islands:No.15&16)		area (ha)	14,396	37,084	4,398	16,566	6,965	6,193	819	5,418	3,793	7,601	103,231
		ratio (%)	13.9	35.9	4.3	16.0	6.7	6.0	0.8	5.2	3.7	7.4	100
Total (including islands)		area (ha)	16,981	37,851	19,763	17,842	7,571	6,663	828	5,418	3,848	7,601	124,366
		ratio (%)	13.7	30.4	15.9	14.3	6.1	5.4	0.7	4.4	3.1	6.1	100

Source: Satellite image analysis by JICA study team

Table 3.4.2 Estimated Freshwater Inflow into the Bay (During Rainy Season)

No.	Name of Sub-catchment	Precipitation (June-Aug.)	Precipitation in Sub-catchment	Runoff Ratio	Evapo-transpiration Ratio	Discharge	
		mm/month	$\times10^6$ m^3/ month	-	-	$\times10^6$ m^3/ month	m^3/s
1	Mip River	320	92.7	0.72	0.08	61.0	23.6
2	Hung Thang Basin	320	2.7	0.68	0.08	1.7	0.7
3	Bai Chay Basin	320	3.2	0.69	0.08	2.1	0.8
4	Troi River	320	76.5	0.69	0.08	48.5	18.7
5	Man River	320	45.7	0.69	0.08	29.1	11.2
6	Dien Vong River	320	96.1	0.72	0.08	63.2	24.4
7	Hong Gai North Basin	320	6.3	0.72	0.08	4.1	1.6
8	Hon Hay South Basin	320	3.0	0.73	0.08	2.0	0.8
9	Ha Tu Basin	320	11.7	0.79	0.08	8.5	3.3
10	Cam Pha West Basin	370	12.8	0.71	0.08	8.4	3.2
11	Cam Pha Central Basin	370	7.0	0.82	0.08	5.3	2.0
12	Cam Pha East Basin	370	5.3	0.79	0.08	3.9	1.5
13	Cua Ong Basin	370	4.7	0.73	0.08	3.1	1.2
14	Mong Duong River	370	36.9	0.77	0.08	26.3	10.1
15	Cat Ba Island	320	42.4	0.70	0.08	27.1	10.5
	Total	-	404.6	-	-	267.2	103.1

Note: Rainfall and evapo-transpiration ratio are quoted from the hydro-meteorological data, Quang Ninh Province, 1996-1997.
Evapo-transpiration ratio equals the amount of evaporation/rainfall.
Runoff ratio is calculated by using land use pattern and coefficient.

Table 3.4.3 Total Pollution Load Generated (Present)

No.	BOD (kg/day)					COD (kg/day)					SS (kg/day)					T-N (kg/day)					T-P (kg/day)				
	Dom.	Ind.	Live.	Non-S.	Total	Dom.	Ind.	Live.	Non-S.	Total	Dom.	Ind.	Live.	Non-S.	Total	Dom.	Ind.	Live.	Non-S.	Total	Dom.	Ind.	Live.	Non-S.	Total
1	870	1	3,190	3,268	7,330	380	6	2,190	4,616	7,190	660	59	11,950	93,109	105,800	160	1	810	2,774	3,750	20	0	370	1,003	1,390
2	380	0	400	111	890	170	0	270	157	600	290	0	1,450	2,167	3,900	70	0	80	84	230	10	0	50	33	90
3	390	0	280	116	790	173	1	190	146	510	300	4	1,010	1,277	2,600	70	0	60	73	200	11	0	30	35	80
4	2,260	3	2,480	2,784	7,530	990	5	1,700	3,981	6,680	1,720	61	9,260	85,442	96,500	410	0	620	2,437	3,470	50	0	290	855	1,200
5	270	0	1,510	1,636	3,420	120	0	1,030	2,334	3,480	210	0	5,630	45,104	50,900	50	0	380	1,385	1,810	10	0	170	498	680
6	2,500	5	3,150	3,450	9,100	1,100	27	2,160	4,989	8,280	1,900	257	11,770	120,506	134,400	450	6	790	3,054	4,300	50	1	360	1,042	1,450
7	2,740	8	650	232	3,630	1,200	32	430	316	1,980	2,080	326	2,359	10,791	15,500	490	4	140	219	850	50	0	80	74	200
8	1,650	9	360	191	2,210	730	11	230	227	1,200	1,250	37	1,260	2,049	4,600	300	12	80	115	510	30	1	40	60	130
9	580	59	1,440	444	2,520	260	224	960	653	2,100	440	5,398	5,180	32,192	43,200	100	57	320	517	990	10	5	180	144	340
10	3,410	2	390	507	4,310	1,500	7	270	695	2,470	2,590	18	1,490	11,046	15,100	610	1	100	385	1,100	70	0	50	152	270
11	760	29	190	358	1,340	330	79	130	455	990	580	344	720	15,545	17,200	140	9	50	311	510	20	1	20	116	160
12	400	338	140	250	1,130	180	1,437	90	320	2,030	300	15,865	510	9,742	26,400	70	460	30	211	770	10	9	10	80	110
13	400	0	120	146	670	170	1	80	202	450	300	9	430	5,639	6,400	70	0	30	127	230	10	0	10	45	60
14	370	43	1,030	1,178	2,620	160	241	700	1,738	2,840	280	2,277	3,850	69,626	76,000	70	51	260	1,233	1,610	10	5	120	364	500
15	0	0	0	1,834	1,830	0	0	0	2,623	2,620	0	0	0	32,569	32,600	0	0	0	1,375	1,370	0	0	0	533	530
Total	16,980	496	15,330	16,505	49,320	7,463	2,071	10,430	23,453	43,420	12,900	24,655	56,850	536,802	631,100	3,060	602	3,750	14,299	21,700	361	21	1,780	5,034	7,190
%	34.4	1.0	31.1	33.5	100	17.2	4.8	24.0	54.0	100	2.0	3.9	9.0	85.0	100	14.1	2.8	17.3	65.9	100	5.0	0.3	24.7	70.0	100

Table 3.5.1 Run-off Ratios of Pollution Loads (Present)

No.	BOD				COD				SS				T-N				T-P			
	Dom.	Ind.	Live.	Non-S.	Dom.	Ind.	Live.	Non-S.	Dom.	Ind.	Live.	Non-S.	Dom.	Ind.	Live.	Non-S.	Dom.	Ind.	Live.	Non-S.
1	0.1	0.5	0.1	0.1	0.5	0.7	0.2	0.5	0.5	0.7	0.3	0.3	0.8	0.8	0.6	0.6	0.9	0.9	0.8	0.8
2	0.2	0.7	0.2	0.2	0.7	0.9	0.5	0.7	0.7	0.9	0.5	0.7	0.9	0.9	0.8	0.8	1.0	1.0	0.9	0.9
3	0.2	0.7	0.2	0.2	0.7	0.9	0.5	0.7	0.7	0.9	0.5	0.7	0.9	0.9	0.8	0.8	1.0	1.0	0.9	0.9
4	0.2	0.7	0.1	0.1	0.7	0.9	0.2	0.5	0.7	0.9	0.2	0.3	0.9	0.9	0.7	0.7	1.0	1.0	0.8	0.8
5	0.1	0.6	0.1	0.1	0.5	0.8	0.2	0.5	0.5	0.8	0.2	0.3	0.8	0.8	0.6	0.6	0.9	0.9	0.8	0.8
6	0.1	0.5	0.1	0.1	0.5	0.7	0.2	0.5	0.5	0.7	0.2	0.3	0.8	0.8	0.6	0.6	0.9	0.9	0.8	0.8
7	0.2	0.7	0.2	0.2	0.7	0.9	0.5	0.7	0.7	0.9	0.5	0.7	0.9	0.9	0.8	0.8	1.0	1.0	0.9	0.9
8	0.2	0.7	0.2	0.2	0.7	0.9	0.5	0.7	0.7	0.9	0.5	0.7	0.9	0.9	0.8	0.8	1.0	1.0	0.9	0.9
9	0.2	0.7	0.2	0.2	0.7	0.9	0.4	0.6	0.7	0.9	0.4	0.6	0.9	0.9	0.8	0.8	1.0	1.0	0.9	0.9
10	0.2	0.7	0.2	0.2	0.7	0.9	0.5	0.7	0.7	0.9	0.5	0.7	0.9	0.9	0.8	0.8	1.0	1.0	0.9	0.9
11	0.2	0.7	0.2	0.2	0.7	0.9	0.5	0.7	0.7	0.9	0.5	0.7	0.9	0.9	0.8	0.8	1.0	1.0	0.9	0.9
12	0.2	0.7	0.2	0.2	0.7	0.9	0.5	0.7	0.7	0.9	0.5	0.7	0.9	0.9	0.8	0.8	1.0	1.0	0.9	0.9
13	0.2	0.7	0.2	0.2	0.7	0.9	0.5	0.7	0.7	0.9	0.5	0.7	0.9	0.9	0.8	0.8	1.0	1.0	0.9	0.9
14	0.2	0.7	0.1	0.1	0.7	0.9	0.2	0.5	0.7	0.9	0.2	0.3	0.9	0.9	0.8	0.8	1.0	1.0	0.9	0.9
15	0.2	0.7	0.1	0.1	0.7	0.9	0.2	0.5	0.7	0.9	0.2	0.3	0.9	0.9	0.8	0.8	1.0	1.0	0.9	0.9

Table 3.5.2 Run-off Pollution Loads into the Bays (Present)

No.	BOD (kg/day)					COD (kg/day)					SS (kg/day)					T-N (kg/day)					T-P (kg/day)				
	Dom.	Ind.	Live.	Non-S.	Total	Dom.	Ind.	Live.	Non-S.	Total	Dom.	Ind.	Live.	Non-S.	Total	Dom.	Ind.	Live.	Non-S.	Total	Dom.	Ind.	Live.	Non-S.	Total
1	87	1	319	327	730	190	4	438	2,308	2,940	330	41	3,585	27,933	31,900	128	1	486	1,665	2,280	18	0	296	802	1,120
2	76	0	80	22	180	119	0	135	110	360	203	0	725	1,517	2,400	63	0	64	68	190	10	0	45	29	80
3	78	0	56	23	160	121	1	95	102	320	210	4	505	894	1,600	63	0	48	58	170	11	0	27	32	70
4	452	2	248	278	980	693	4	340	1,990	3,030	1,204	55	1,852	25,632	28,700	369	0	434	1,706	2,510	50	0	232	684	970
5	27	0	151	164	340	60	0	206	1,167	1,430	105	0	1,126	13,531	14,800	40	0	228	831	1,100	9	0	136	399	540
6	250	2	315	345	910	550	19	432	2,494	3,500	950	180	2,354	36,152	39,600	360	5	474	1,832	2,670	45	0	288	833	1,170
7	548	6	130	46	730	840	29	215	222	1,310	1,456	293	1,175	7,554	10,500	441	4	112	175	730	50	0	72	67	190
8	330	6	72	38	450	511	10	115	159	800	875	33	630	1,434	3,000	270	11	64	92	440	30	1	36	54	120
9	116	41	288	89	530	182	201	384	392	1,160	308	4,858	2,072	19,315	26,600	90	51	256	413	810	10	5	162	130	310
10	682	1	78	101	860	1,050	6	135	487	1,680	1,813	16	745	7,732	10,300	549	1	80	308	940	70	0	45	137	250
11	152	20	38	72	280	231	71	65	318	690	406	310	355	10,881	12,000	126	8	40	249	420	20	1	18	105	140
12	80	236	28	50	390	126	1,293	45	224	1,690	210	14,279	255	6,819	21,600	63	414	24	168	670	10	9	9	72	100
13	80	0	24	29	130	119	1	40	142	300	210	8	215	3,948	4,400	63	0	24	103	190	10	0	9	40	60
14	74	30	103	118	320	112	217	140	869	1,340	196	2,049	770	20,888	23,900	63	46	208	986	1,300	10	5	108	328	450
15	0	0	0	183	180	0	0	0	1,311	1,310	0	0	0	9,771	9,800	0	0	0	1,100	1,100	0	0	0	479	480
Total	3,032	346	1,930	1,886	7,170	4,904	1,857	2,785	12,296	21,860	8,476	22,126	16,364	194,000	241,100	2,088	541	2,542	9,753	15,520	353	21	1,483	4,191	6,050
%	42	5	27	26	100	22	9	13	56	100	4	9	7	81	100	17	3	16	63	100	6	0	25	69	100