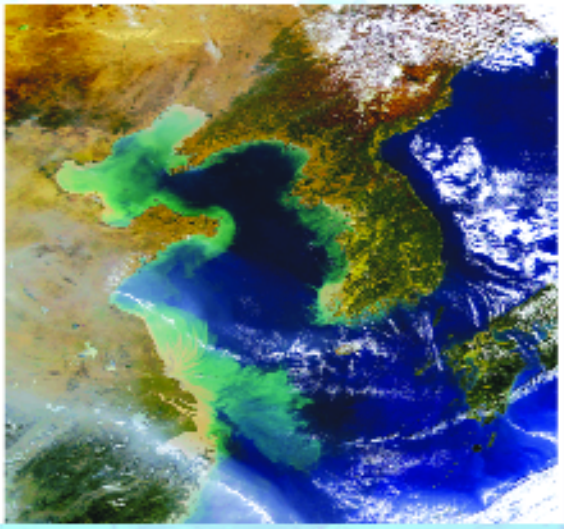


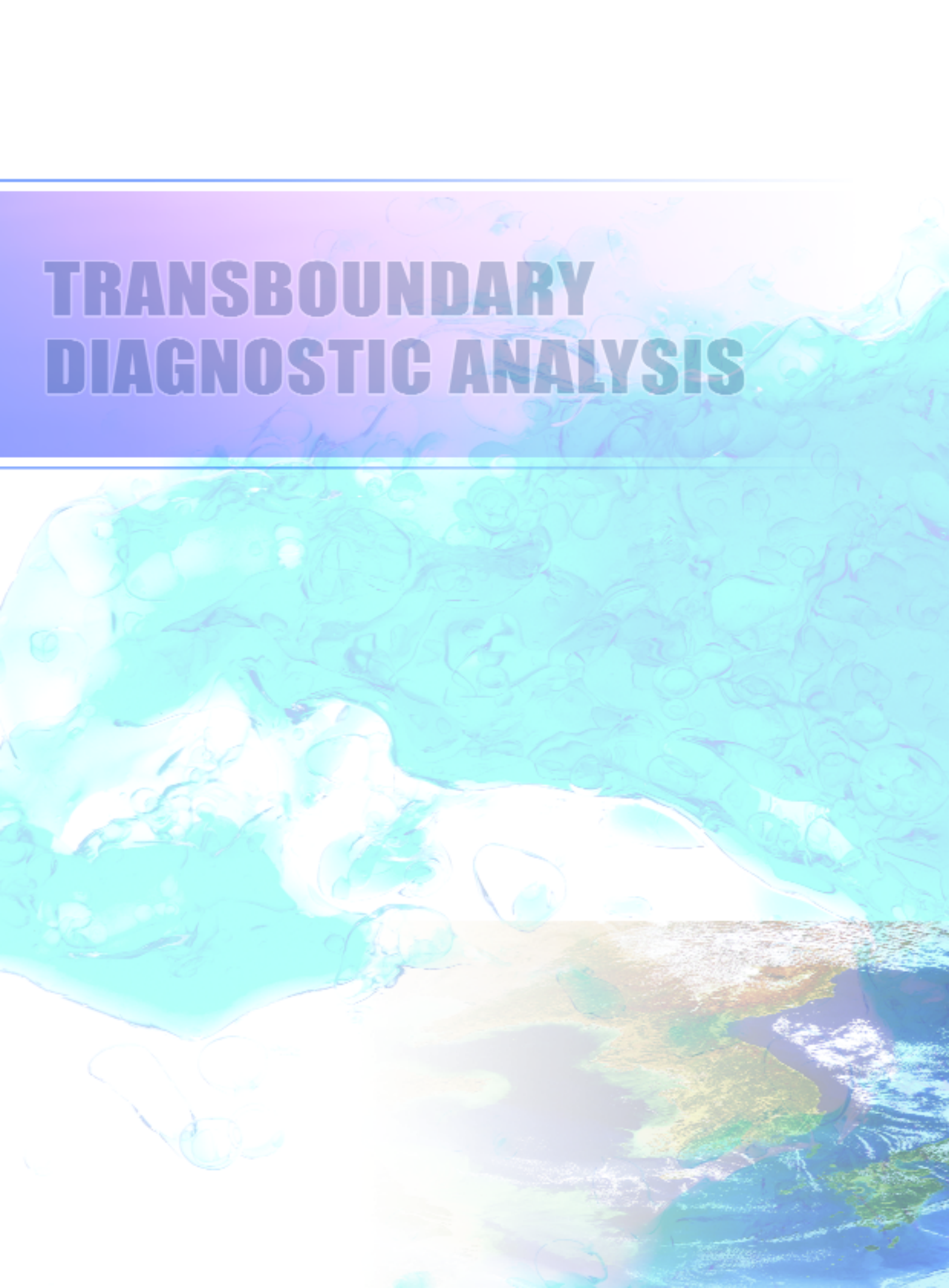
"REDUCING ENVIRONMENTAL STRESS IN THE YELLOW SEA LARGE MARINE ECOSYSTEM"

TRANSBOUNDARY DIAGNOSTIC ANALYSIS

for the Yellow Sea LME

by
J.M. Bewers, Ph.D., C.Phys., F.Inst.P., MSRP

TRANSBOUNDARY DIAGNOSTIC ANALYSIS



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This document presents the transboundary diagnostic analysis (TDA) for the Yellow Sea Large Marine Ecosystem. It was a principal output/deliverable of the UNDP/GEF Project, "Reducing Environmental Stress in the Yellow Sea Large Marine Ecosystem." The TDA was prepared from August to December 2006, and is based on studies and evaluations conducted within the project to September 2006.

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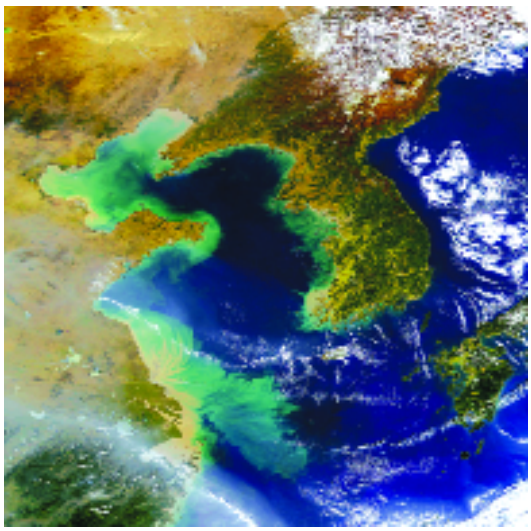

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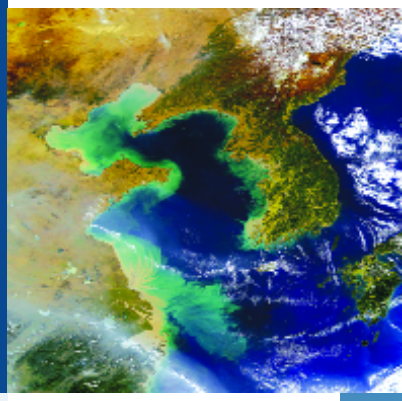
1. INTRODUCTION



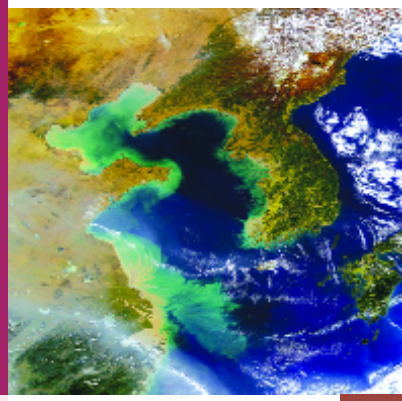
This document presents the transboundary diagnostic analysis (TDA) for the Yellow Sea Large Marine Ecosystem (YSLME). It is a principal output/deliverable of the UNDP/GEF Project entitled "Reducing Environmental Stress in the Yellow Sea Large Marine Ecosystem". The TDA was prepared during the period August to December 2006 and is based on studies and evaluations conducted within the project to September 2006.

The TDA is used as a basis for focusing on existing problems and impending threats to the critical ecosystem of the YSLME. It is intended to provide a sound basis for the preparation of a Strategic Action Programme (SAP) for the YSLME in the next phase of project activities. The project brief states: *"The SAP will identify priority actions to be taken by the participating countries to restore and preserve the YSLME. The SAP will adopt a comprehensive approach and will address land and sea-based sources of marine pollution, degradation of critical habitats and over-fishing."* Accordingly, the TDA must address all major problems in the Yellow Sea and determine their immediate, intermediate and root causes. This is done as a means of identifying options for management intervention by the riparian states acting in concert and sets the stage for the selection of interventions for inclusion in the SAP.

The TDA process is predominantly a scientific and technical exercise. Necessarily, it does encroach upon the socio-economic and political arenas to the extent required to undertake the root cause analyses and the identification and analysis of options for intervention. In contrast, the formulation of the SAP is primarily a socio-economic and political process. It is one in which the social and political advantages and disadvantages of options for intervention are fully considered and debated prior to the consensual adoption of a suite of

interventions for inclusion in the SAP. Inevitably, the SAP formulation will require some degree of technical and scientific support to undertake an assessment of the positive and negative consequences of all the options for intervention. It is intended that much of this information be provided in the technical analysis of the environmental problems and options for intervention in the TDA.

2. TRANSBOUNDARY DIAGNOSTIC ANALYSIS – THE GEF CONTEXT



The GEF advocates a process of formal assessment of problems and priorities referred to as a Transboundary Diagnostic Analysis (TDA). It was referred to in the First Study of GEF's Overall Performance (GEF 1998) in the following way:

"The centerpiece of the GEF strategy .... is the concept of 'strategic joint fact finding' as a means of arriving at a consensus on what actions are needed to establish threats ... collaborating states establish technical teams that work to establish a common baseline of facts and analysis of the problem in the form of a transboundary diagnostic analysis (TDA), which is then used to set (national) priorities for actions to address threats to international waters in the form of the SAP."

The Second Overall Performance Study (OPS2) (GEF 2002) gave particular recognition to the utility of TDA to projects in the International Waters Focal Area as follows:

"GEF-supported activities under the international waters focal area have contributed significantly to the implementation of existing global and regional agreements that address protection and restoration of freshwater and marine ecosystems."

"Examining the results of the international waters portfolio, one particular operational approach demonstrates considerable merits: A science-based Transboundary Diagnostic Analysis (TDA) is conducted at the preparatory stage, before a strategic action program (SAP) is elaborated. It has similarities to the process embedded in enabling activities in support of UNFCCC[1] or CBD[2]. Furthermore, the GEF is one of very few

1 United Nations Framework Convention on Climate Change (FCCC, 1992)
2 Convention on Biological Diversity

financial mechanisms available to support comprehensive analysis and integrated planning in multinational water bodies. The TDA-SAP process has provided a mechanism for the GEF to contribute substantially to the in-country strengthening of institutions and to promote strategic alliances among institutions in different countries, thus promoting the development of effective monitoring systems and improved management capacities."

"The TDA-SAP process is a valuable part of project preparation to build capacity, receive scientific and technical inputs, and encourage participation by the political authorities involved and other important institutional actors and stakeholders. In addition, it is recognized as an essential process for securing multicountry political agreement to focus on transboundary environmental priorities. As stated by the OPS1 team, "The centerpiece of the GEF strategy on International Waters is the concept of 'strategic joint fact finding' in the form of a transboundary diagnostic analysis (TDA), which is then used to set national priorities for actions to address threats to international waters in the form of a strategic action program (SAP)." The OPS2 team underscores this statement and recommends that the science-based TDA continue to be the basis for facilitating country agreements on SAPs which can mobilize multidonor support for remedying or preventing environmental threats to international waters."

OPS2 not only recommended that TDA continue to be used for the preparation of SAPs in International Waters projects but also recommended that a similar mechanism be used in the new focal area of land degradation. The relevant recommendation is as follows:

"The GEF should review and rationalize the number and objectives of operational programs in light of the lessons learned in order to ensure consistency and a unified focus on delivering global environmental benefits. Furthermore, to ensure quality outcomes that focus on global environmental benefits, OPS2 recommends that GEF make a special effort to use scientific analysis as a constant foundation for the planning and implementation of new projects in all focal areas. The science-based Transboundary Diagnostic Analysis (TDA) should continue to be the basis for facilitating regional agreements on actions to address threats to international waters and for developing strategic action programs (SAPs). OPS2 further recommends the extension of a similar approach to land degradation, as it is now becoming a new focal area."

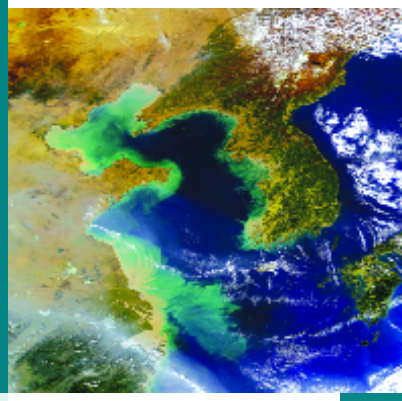
The Third Overall Performance Study (OPS3) (GEF, 2005) later observed:

"Institutional strengthening at the national and regional level resulting partly or totally from GEF projects has proven useful in situations requiring an immediate response. The Transboundary Diagnostic Analysis/Strategic Action Program (TDA/SAP) process has provided a mechanism for the GEF to contribute substantially to the in-country strengthening of institutions and to promote strategic alliances among institutions in different countries, thus promoting the development of effective monitoring systems and improved management capacities. The TDA/SAP tool is a good mechanism for harmonizing the IW scientific approach with a policy approach, and a positive by-product is capacity building."

OPS3 further noted that the Third International Waters Program Study (Mee et al., 2005) had found that the TDA can be an effective tool if it *"sets appropriate boundaries, identifies all relevant stakeholders, conducts studies by joint fact finding (without excluding any relevant regional expertise), includes an appropriate balance of disciplines, identifies the socioeconomic causes of the transboundary problems identified, evaluates the institutional capacity, and makes all the information available to the stakeholders in a concise and non-jargonistic manner."*

The preparation of a TDA is therefore considered by the GEF as an effective and appropriate approach to the formulation of SAPs for international waters areas.

3. THE NATURE AND OBJECTIVES OF TRANSBOUNDARY DIAGNOSTIC ANALYSIS



A Transboundary Diagnostic Analysis (TDA) is a scientific and technical assessment of an international waters area that identifies and quantifies the environmental issues and problems in the subject area and establishes their immediate, intermediate and fundamental (root) causes. The analysis involves an identification of the causes and impacts of environmental disturbances and/or threats and assesses the scale and distribution of impacts at national, regional and global levels, predominantly in socio-economic terms. The identification of causes specifies the practices, sources, locations and human activity sectors from which environmental degradation arises or is threatened.

Thus, the purpose of a TDA is to assess the relative importance of environmental disturbances and threats to international waters and their causes as a means of identifying potential remedial and/or preventative actions. A TDA thus provides the basis for the formulation of a Strategic Action Programme (SAP) embodying specific actions, or interventions, that can be adopted multilaterally to restore, or preserve from further degradation, a specific international waters area.

A TDA should yield a list of priority issues affecting an international waters area, their causes and the origins of those causes. Although TDAs can be conducted by, and within, single countries, the need to identify transboundary effects and causes makes it desirable that the TDA process be conducted multilaterally with the participation of all riparian states of an international waterbody. Ideally, the sequence of causes should be identified in a hierarchical manner from technical perspectives, through management and socio-economic perspectives to the political (i.e., policy) level. Accordingly,

the term 'root causes' should be reserved for the most fundamental in this hierarchy of causes. In GEF parlance, this sequential identification of the hierarchy of causes is conceptually known as a "causal chain". It is intended to facilitate the specification of potential interventions to either remedy current environmental problems or to obviate environmental threats. The most effective of these options for intervention then constitute the basis of a Strategic Action Programme (SAP) that can be formulated and applied in a coordinated manner by all riparian countries.

3.1. The Components of Transboundary Diagnostic Analyses

Mee (2002) and Pernetta (2002) have outlined, in informal documents, the nature and components of TDAs in a more detailed manner than that available from contemporary GEF documents. Pernetta specified the principal components of a TDA while Mee provided an abundance of ancillary detail in an attempt to assist those involved in the process at the project level. Both of these authors' outlines are consistent with the more elementary specifications contained in the report of the Second International Waters Program Study (Bewers and Uitto, 2001). The following explanation of TDA components is based on material from these sources as well as other GEF documents. These elements are generic and apply to any TDA relating to a water body whether provincial, national or international.

Component 1: Scope of the Transboundary Diagnostic Analysis

This component contains a definition of the subject area for which the TDA is conducted. Generally this is a geographical definition of the area to which the TDA applies. This component also defines the disciplinary scope of the TDA, which specifies the topics or subject areas that are to be covered.

Component 2: Assessment of Problems

The second component in the conduct of a TDA is the identification of existing problems. These problems relate to compromises in the quality or abundance of resources and amenities of a specific international waters area such as a freshwater course, a lake or a coastal marine or regional sea area. Such compromises can involve unsuitability of water for irrigation or animal or human

drinking purposes, poor quality of fish for human consumption, undue algal growth resulting in oxygen deficiency and adverse effects on organisms (e.g., fish kills), and/or unpleasant odours, aesthetic effects or high turbidity reducing the recreational and tourism value of an area. There are many such potential problems and the foregoing is not intended to constitute an exhaustive list. Frequently, the 'problems' are merely observations of peculiarities or effects, for example frequent fish kills, without the immediate cause being known. Thus, characterization of problems must be carried out by those familiar with the subject area.

Component 3: Identification of Priorities

This constitutes an evaluation of the relative severity of the problems identified in the previous component. This again must be based on local knowledge. The wider the body of local knowledge and experience involved in the conduct of the TDA, the more objective the specification of priorities is likely to be. The evaluation of priorities is based on the severity of the problem in the context of its effects on those drawing their livelihood from the water area concerned, the reduction in economic gains from the area in relation to its potential (fisheries yield or tourism for example) and effects on other aspects of life within the communities affected. The end result of Component 3 should be a consensus list of prioritized 'problems'.

Component 4: Identification of Causes

Components 4 and 5 constitute the Causal Chain Analysis. Component 4 involves the identification of causes for each of the problems identified and prioritized in Components 2 and 3. These causes should stem from the immediate to the proximal causes to as high a level of hierarchy as possible, extending up to the policy level wherever feasible. It is best explained by example. Let us say that one of the identified problems is abundant algal growth that is impeding navigation, causing odours and interfering with the use of water for irrigation (clogging of pumps), animal watering and human consumption. The most immediate cause is likely to be excessive nutrient supply to the water body. The cause of the excessive nutrient supply is attributable to animal wastes or fertilizer washoff from agricultural activities on adjacent land and excessive discharge of poorly treated human sewage. Each of these secondary causes will then have causes at higher levels in the hierarchy. The excessive discharge of animal wastes may be due to farm management practices that have not provided sufficient land to neutralize nutrients in animal wastes. Excessive fertilizer washoff can be due either to the application of fertilizers beyond the amounts needed for adequate fertilization of crop growth or the use of fertilizers on land immediately adjacent to the water body concerned without

regard for washoff and runoff. Excessive inputs of inadequately treated human wastes may be due to the type of practice carried out in the immediate area such as inadequate sewage collection and treatment infrastructure for a large urban area or the mode of sewage collection and discharge that is incompatible with the other uses of the water body concerned.

In turn, each of these causes will have a further level of more remote, but more fundamental, causes. These might include unjustifiably low prices for fertilizers (e.g., as a result of farm subsidies), over-promotion of intensive agriculture for animal husbandry and crops, inadequate imposition and regulation of boundary zones between agricultural areas and water bodies, or insufficient emphasis on adequate human sewage management in the vicinity of the water body.

The next level of cause might include unreasonable and incautious incentives for agricultural production at the policy level, inadequate policies regarding protection of water bodies from adjacent activities such as agriculture, inadequate policy attention to sewage management and a predominance of sector-by-sector regulation at the policy level. It might also include a lack of compliance with existing legislation and regulations.

The examination of the sequence of causes should continue until the highest possible level is reached. Usually, within a national context, this is at the federal policy level, although some problems will arise from causes in other, generally riparian, jurisdictions. These should be specified. Indeed, there may be root causes of a global nature, especially in relation to the symptoms of climatic change[3]. The causal chain analysis should extend to such root causes if they contribute to problems identified and prioritized at the beginning of the TDA. Most usually, the highest policy levels that can be addressed in regional TDAs are national legislation and policies of the riparian states concerned. However, in cases where some of the countries are party to larger multilateral community agreements, such as that within the European Union, the policy level will immediately extend to the multilateral level.

Component 5: Quantification of Causes

Biological Diversity

This component is one of greater complexity and difficulty. The previous component should have produced a hierarchy of causes of problems in dendritic (branching) form. Causes at

3 The term "climatic change" is used in this document to avoid the implicit connection with human influence that is assumed in the definition of "climate change" under the FCCC, 1992. The term "climate change" is only used in the specific context of the FCCC, 1992, and the Kyoto Protocol, 1997.2 Convention on Biological Diversity

each level can have multiple causes at higher levels as explained in the description of Component 3. Consequently, there can be branching of causes as one proceeds from the lower to the higher levels. However, at the highest levels, there frequently occurs some commonality among the root causes, especially those of a policy nature.

Component 5 involves the quantification of causes. It requires that the relative significance of causes at each level be quantified. Thus, in the example given above, if excessive algal growth is due to the over-application of fertilizers in local agriculture, this is the dominant cause. A secondary cause might then be excessive washoff of animal wastes. The quantification required at Component 5 is to designate relative weightings to the causes at each level of hierarchy for each of the problems at the base of the causal chain analysis. The dendritic diagram of root causes therefore has the added feature of relative weightings of causes relating to a given problem at each level of branching in the hierarchy. As stated, this is a difficult thing to do. Frequently, it may only be possible to provide a semi-quantitative rating of causes based on local knowledge as represented by those involved in the TDA. Nevertheless, such semi-quantitative ratings are still likely to constitute an effective approach as long as they have been derived through a transparent and internally consistent process.

Component 6: Discrimination between National and Transboundary/ Incremental Causes

The next component of the TDA process is the discrimination among causes of national origin and those of transboundary or incremental origin. In many cases, the sources of the fundamental (root) causes will be immediately evident and it will be a simple matter to assign them to national, regional or broader origins. Inevitably, in some other cases, there will be several origins (national, multilateral, international) of the root causes. Partitioning among these origins is essential for determining the national and transboundary contributions. Such discrimination is obviously of direct relevance to the development of GEF projects for which quantification of transboundary or incremental causes, and therefore costs, is essential. However, there are concomitant benefits to the countries concerned in addressing environmental problems adversely affecting their development. Clearly, causes of national problems that have origins within the same national jurisdiction are tractable to national action alone. Transboundary causes have to be dealt with in a regional context and sometimes in a global context and in the absence of cooperative arrangements, such as those promoted by the GEF, cannot be addressed by individual national actions alone.

Component 7: Identification and Analysis of Options for Intervention

The penultimate component of the TDA process is the identification and analysis of options for intervention to rectify the identified priority problems. The causal chain provides the basis for identifying such options. Options for intervention to remediate the original problem will exist at all levels in the causal chain as depicted in Figure 1. The higher in the causal chain that an intervention is made, the greater will be the probability of effectiveness and sustainability. Nevertheless, options for intervention will exist at each level in the causal chain and the effectiveness and consequences of interventions at all levels of the causal chain should be assessed in relation to each environmental problem or groups of problems having similar causal chain entries and common root causes.

The analysis of options will include a specification of the nature of the potential intervention, its likely effectiveness in eradicating the problem and all the other consequences of the intervention, both positive and negative. The negative aspects of interventions will include their cost as well as any other adverse effects on society of a socio-economic or heritage nature. As the potential interventions are analysed for a variety of problems, it is likely that crosstalk[4] (i.e., interactions among potential interventions) will be identified in which an intervention to deal with one problem has either positive or negative effects on others. The analysis of options can also be a lengthy and controversial stage in a TDA but it is well worth the investment of effort in preparing the groundwork for the preparation of the subsequent regional or multilateral SAP.

4 This is a scientific term that in everyday language is somewhat analogous to "interactions."

Figure 1. Hypothetical Causal Chain Depicting Options for Intervention

Issue/Concern	Fundamental Problem/Driver	Priority	Trend	Primary Cause(s)	Secondary Cause(s)	Tertiary Cause(s)	Quaternary Cause(s)	Root Cause(s)
Eutrophication and Harmful Algal Blooms	Nitrogen Enrichment			Sewage discharge (treated and untreated) into the sea and rivers.	No tertiary sewage treatment	Little attention given to the capacity of the Yellow Sea to absorb Nitrogen	No quantitative knowledge of capacity of system to absorb Nitrogen	Limited application of research knowledge to assimilative capacity calculations
					Inadequate urban sewage treatment capacity	Korea - limited investment in urban infrastructure China - rapidly increasing urban populations.		Limited influence of environmental constituency on government policies
					Inadequate storm water drainage / separation of sewage and stormwater drainage systems	Cost of separating storm and sewage water in long established urban areas.		
						Where such separation exists, it is frequently overwhelmed by major storm events.		

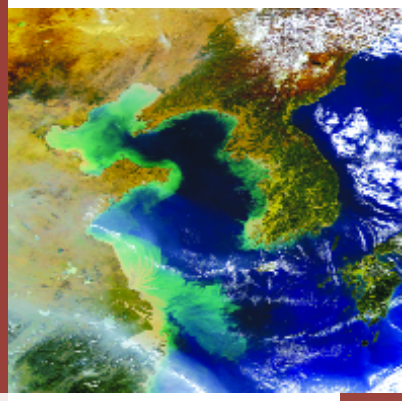
Options for Intervention
Interventions can be applied to any level of cause

Summary of TDA Components

Components 1 to 7 inclusive constitute the essential features of a Transboundary Diagnostic Analysis. It should be stressed that a particular TDA will not always be structured in the same sequence as that presented above. It is only essential that the activities covered by these components are included in the TDA or SAP in an appropriate and coherent manner. The TDA provides a basis for the subsequent formulation of a Strategic Action Programme (SAP) by specifying the priority problems and identifying and analysing options for intervention. The hierarchy of causes identified in the TDA is essential for maximizing the effectiveness of potential interventions. These interventions are generally best directed at the more fundamental of the causes. This is especially true if there are common higher-level causes of more than one problem. The analysis of options for intervention prepares the ground both for addressing problems that are dominantly of national origin and for dealing multilaterally with transboundary causes within a regional context. One final point is worth making. Throughout, there has been reference to problems as being those involving contemporary compromises to the benefits obtained from a water body. It should be stressed, as implied at the outset, that a TDA can also include the evaluation of problems that constitute threats of future environmental damage or compromise.

In some cases, a TDA can include a stakeholder analysis and the consideration of infrastructural weaknesses. In other cases, such analyses are included in the SAP formulation process. In the TDA for the Yellow Sea presented here, these topics are intended to be included in the SAP preparation process and are only referred to here to the extent that they relate to the causes of environmental problems subjected to causal chain analysis.

4. SCOPE OF THE TDA FOR THE YELLOW SEA LME



4.1. Geographical Scope

The geographical scope of the TDA is that of the subject region defined for the purposes of the project brief. The definition in the project brief is as follows:

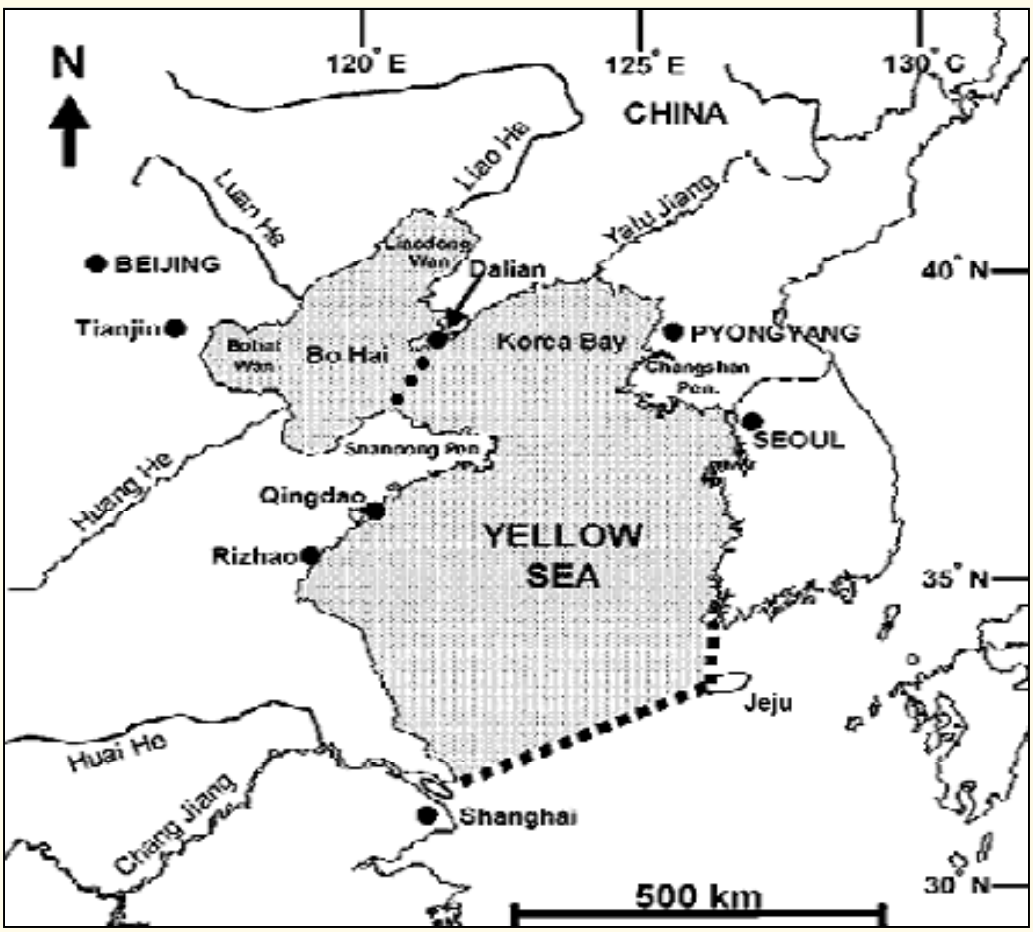
"The Yellow Sea is the semi-enclosed body of water bounded by the Chinese mainland to the west, the Korean Peninsula to the east, and a line running from the north bank of the mouth of the Yangtze River (Chang Jiang) to the south side of Jeju Island. It covers an area of about 400,000 km² and measures about 1,000 km (length) by 700 km (maximum width). The floor of the Yellow Sea is a geologically unique, post-glacially submerged, and shallow portion of the continental shelf. The seafloor has an average depth of 44 m, a maximum depth of about 100 m, and slopes gently from the Chinese continent and more rapidly from the Korean Peninsula to a north-south trending seafloor valley with its axis close to the Korean Peninsula. This axis represents the path of the meandering Yellow River (Huang He) when it flowed across the exposed shelf during lowered sea level and emptied sediments into the Okinawa Trough. The Sea annually receives more than 1.6 billion tons of sediments, mostly from the Yellow River (Huang He) and Yangtze River, which have formed large deltas. The Yellow Sea is connected to the Bo Hai Sea in the north and to the East China Sea in the south, thus forming a continuous circulation system. Major rivers discharging directly into the Yellow Sea include the Han, Yangtze, Datung, Yalu, Guang, and Sheyang."

Unfortunately, while the penultimate sentence of this definition indicates that the Bohai Sea is not part of the project area, the definition in the first part of the paragraph does not specify a northwestern boundary for the project area other than the coast of the People's Republic of China (PRC). Through discussions with the Project Management Office (PMO), however, it

was established that the northwestern boundary of the project area is a line drawn in a northeasterly direction from Penglai on the Shandong Peninsula to Dalian as correctly stated in the preliminary TDA (Annex E to the project brief). To the west of this line is the Bohai Sea, which lies outside the project area. A limit also needs to be drawn between the north coast of Jeju Island and the Korean mainland. All these boundaries to the area covered by the YSLME project are depicted in Figure 2. Accordingly, the first sentence of the paragraph that constitutes a definition of the subject area, should read:

"The Yellow Sea is the semi-enclosed body of water bounded as follows: to the west by the Chinese mainland south of Penglai and a line from Penglai to Dalian; to the east by the Korean Peninsula and Jeju Island and a line drawn from Jindo Island off the south coast of the Korean mainland to the north coast of Jeju Island; and to the south by a line running from the north bank of the mouth of the Yangtze River (Chang Jiang) to the southwestern coast of Jeju Island."

Figure 2. Boundaries of the Yellow Sea LME.



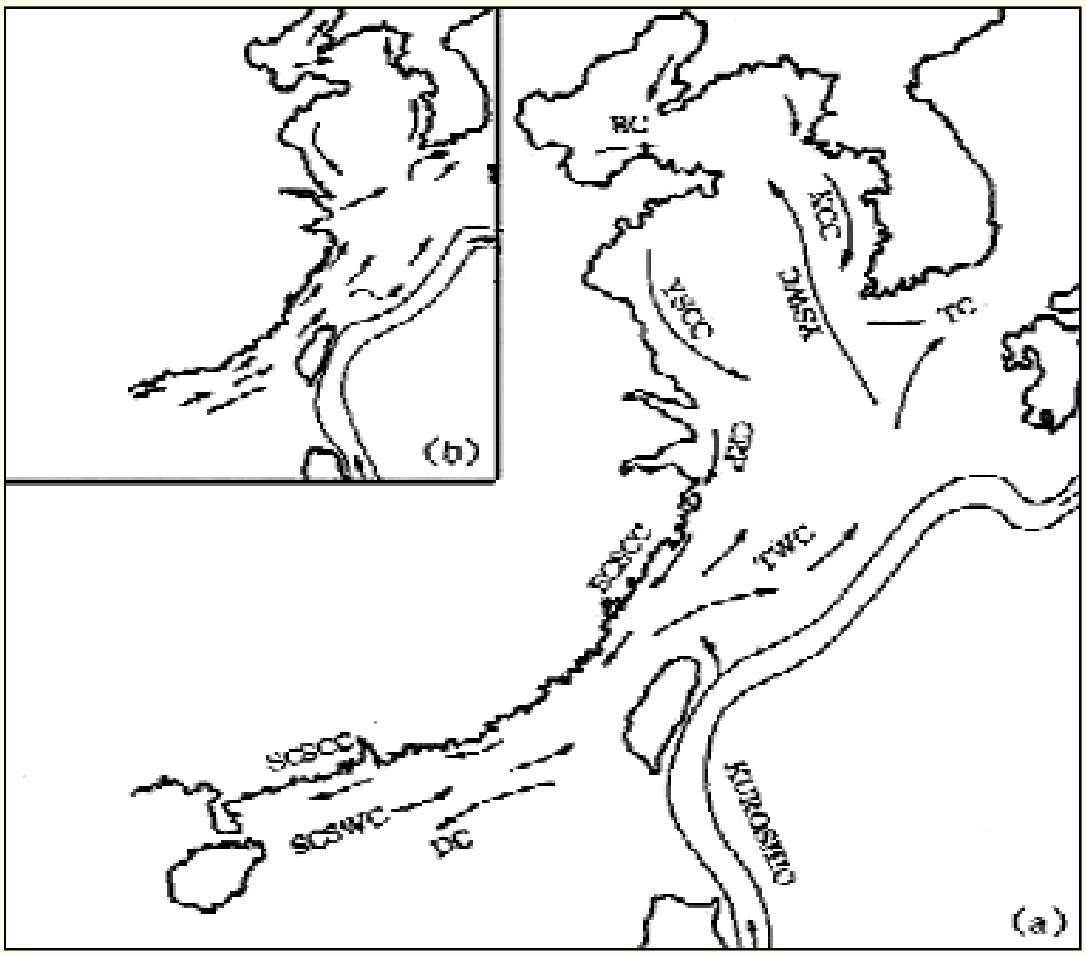
The hydrographic properties and circulation of the Yellow Sea are created predominantly by winter cooling and summer heating, freshwater discharge from rivers and, arguably, the inflow of warm saline waters in a branch of the Kuroshio[5] . Wind-forcing and freshwater runoff are also influenced by the cold and dry northerly winter monsoon and the warm humid southerly summer monsoon.

The major water masses of the Yellow Sea are the Yellow Sea Cold Water, the Yellow Sea Warm Current Water and Yangtze River mixed water. Yellow Sea Cold Water is formed during winter cooling and occupies the lower layer of the basin. This water mass survives throughout the summer. The Yellow Sea Warm Current Water is relatively saline and flows northwestward between Sokotra Rock and Jeju Island, into Jeju Strait and the eastern Yellow Sea. The predominant direction of outflow from the Yangtze is to the south consistent with geostrophy but, in the summer, Yangtze River mixed water extends northeastward toward Jeju Island and lowers the salinity of the waters to the west of Jeju Island. Current speeds in the eastern part of the Yellow Sea are usually less than 0.2 knots except for areas near to Huksando and Jeju Islands where stronger currents are observed.

In summer, the circulation of the Yellow Sea comprises southward flowing Chinese coastal water, northward flowing Yellow Sea Warm Current influenced by the Kuroshio to the east, and the northeastward movement of water from the East China Sea with a central cyclonic gyre[6] (See Figure 3 after Su, 1998). In winter, the central cyclonic gyre is not as pronounced but, apart from the southward coastal flow along the Korean Peninsula, the overall circulation of the Yellow Sea remains essentially cyclonic. This circulation pattern is reflected in the water velocities across a zonal transect at 36oN shown in Figure 4 (after Qiao, 2006).

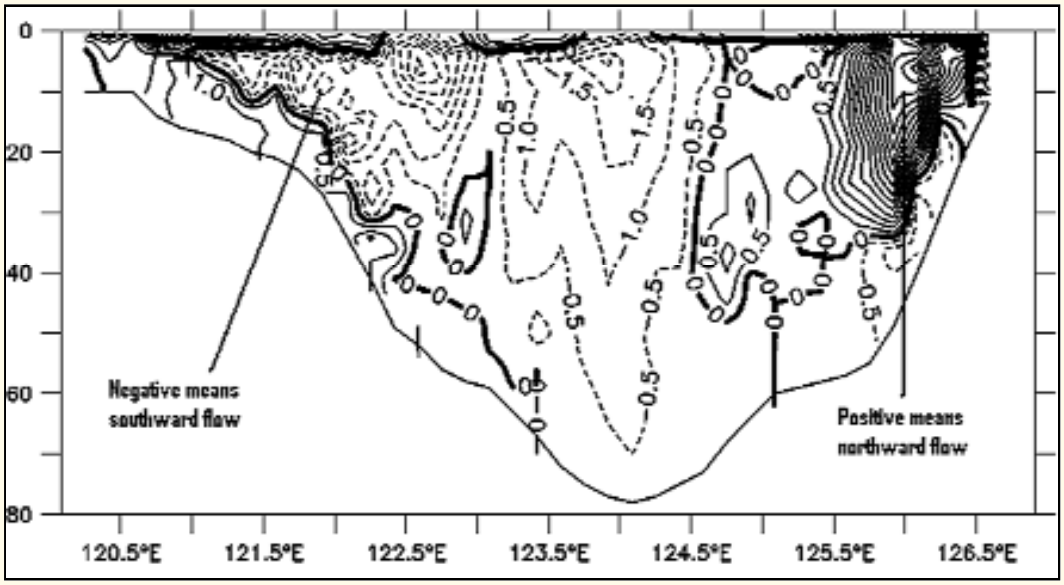
5 The extent to which some Kuroshio water enters the southeastern Yellow Sea to become part of the Yellow Sea Warm Current remains a matter of scientific debate.
6 Anticlockwise circular circulation of water in the horizontal

Figure 3. Yellow Sea Circulation in: (a) Winter; and (b) Summer.



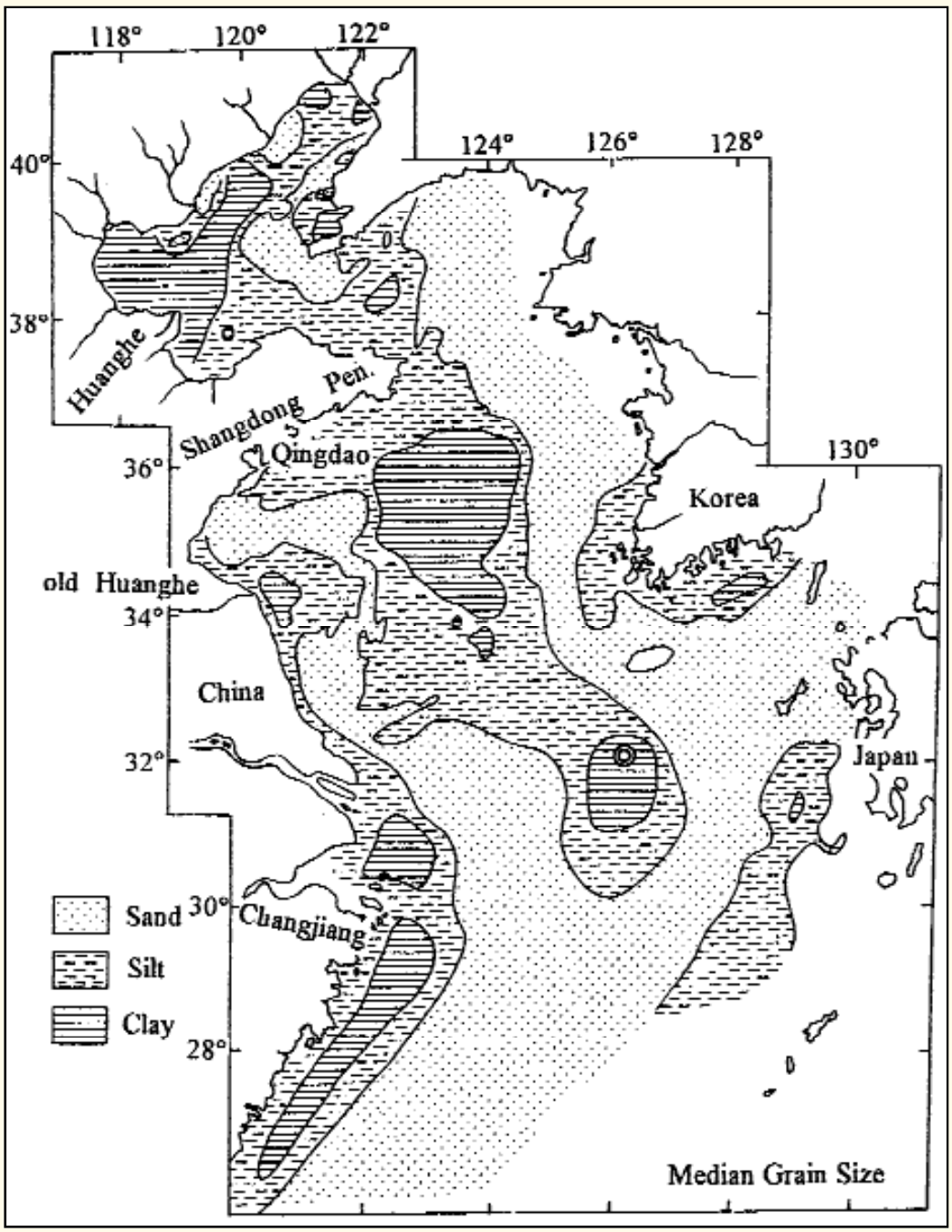
Key to acronyms: BCC = Bohai Coastal Current; CRP = Changjiang River Plume; DC = Dongsha Current; ECSCC = East China Sea Coastal Current; KCC = Korean Coastal Current; SCSCC = South China Sea Coastal Current; SCSWC = South China Sea Warm Current; TC = Tsushima Current; TWC = Taiwan Warm Current; YSCC = Yellow Sea Coastal Current; and YSWC = Yellow Sea Warm Current.

Figure 4. Water Velocities in cm/s across a Zonal Section at 36°N



The floor of the Yellow Sea is a geologically unique, post-glacially submerged and shallow portion of the continental shelf. The sediments of the Yellow Sea are mostly terrigenous, carried by rivers and winds from the surrounding lands. The annual input of fine-grained detritus to the Bohai Sea was, until recently, approximately 1 billion tonnes per year. Over 90% of this sediment load has been delivered historically by the Yellow River but this has already been reduced and is predicted to fall to about 300 million tonnes by 2019 as a result of engineering works on the Yellow River. Excluding the Changjiang (Yangtze River), about 50 million tonnes of sediment are discharged by rivers directly to the Yellow Sea proper, including a considerable amount of coarse-grained material from rivers draining the Korean Peninsula. However, these inputs are probably dwarfed by the portion of the ca. 500 million tonnes per year of alluvial sediment that is discharged by the Changjiang that enters the Yellow Sea. Terrigenous sediment is distributed by tidal currents, longshore currents, waves and the Yellow Sea Warm Current. Fine sediment is deposited where current and wave actions are lowest. As a result, fine-grained surficial sediments are found in the central region of the Yellow Sea, on the Chinese coast and on the southwest and southern coasts of Korea. Sandy sedimentary facies exist in the eastern central portion of the Yellow Sea and central and northern coastal areas of the Korean Peninsula as shown in Figure 5 taken from the Chinese PDF-B national report (YSLME 1999).

Figure 5. Surficial Bottom Sediment Grain-Size Distribution in the Yellow and Bohai Seas.



4.2. Disciplinary Scope

The disciplinary scope of the TDA is defined by the project brief in terms of the objectives and components of the YSLME project. The scientific and technical scope of the project is reflected by the responsibilities of the Regional Working Groups established in relation to each of the technical components of the project. These cover the topics of pollution, biodiversity, fisheries and ecosystem dynamics. Collectively, these groups cover all the project and objectives summarized in Table 1 of the Project Document. This table is reproduced below in a slightly amended form.

Table 1. Project Objectives and Components.

Objective	Component
I Develop Regional Strategies for Sustainable Management of Fisheries and Mariculture	A. Stock Assessment
	B. Carrying Capacity in Fisheries and Mariculture
	C. Mariculture Production
	D. Disease in Mariculture
	E. Regional Fisheries Agreements and National Laws
	F. Fisheries Management Plan
II Propose and Implement Effective Regional Initiatives for Biodiversity Protection	A. Habitat Conservation
	B. Vulnerable Species
	C. Genetic Diversity
	D. Introduced Species
	E. Biodiversity Regulations
	F. Regional Biodiversity Assessment & Regional Biodiversity Action Plan
III Propose and Implement Actions to Reduce Stress to the Ecosystem, Improve Water Quality and Protect Human Health	A. Stressors to Ecosystem
	B. Carrying Capacity of Ecosystem
	C. Contaminant Inputs
	D. Contaminant Levels
	E. Harmful Algal Blooms and Emerging Disease
	F. Hot Spot Analysis
	G. Emergency Planning and Preparedness
	H. Legal and Regulatory
	I. Fate and Transport Analysis to Facilitate SAP Analysis

The disciplinary scope of the TDA can be further defined in terms of the primary environmental management issues addressed in the project for which appropriate interventions are to be included in the SAP. These primary issues are:

1. Sustainable Management of Fisheries and Mariculture;
2. Biodiversity Protection;
3. Reductions in Stress on the Ecosystem, Improvement of Water Quality and the Protection of Human Health; and
4. Institutional Development and Capacity-Building.

The YSLME project planned to complete "regional syntheses" to outline the status and circumstances pertaining to four topics: (i) sustainable management of fisheries and mariculture; (ii) biodiversity protection; (iii) stress on the ecosystem, water quality and the protection of human health; and (iv) institutional development and capacity-building. The planned content of these syntheses is shown in Box 1.

The organization of project activities has, however, been broken down into a slightly revised set of components each of which has been assigned to a Regional Working Group (RWG). The primary variance from the planned structure is the splitting of the third topic in Box 1 into two sub-activities dealing separately with pollution and the ecosystem. This yields five topics, each of which is assigned to a project regional working group (RWG) as follows:

1. Sustainable Management of Fisheries and Mariculture –RWG on Fisheries (RWG-F);
2. Biodiversity Protection –RWG on Biodiversity (RWG-B);
3. Ecosystem – Ecosystem RWG (RWG-E);
4. Pollution – RWG on Pollution (RWG-P); and
5. Institutional Development and Capacity-Building – Investment RWG (RWG-I).

The Regional Scientific and Technical Panel (RSTP) is responsible for cross-disciplinary issues.

BOX 1
YSLME Project Regional Syntheses

Sustainable Management of Fisheries and Mariculture

This synthesis covers the following topics: stock assessment, carrying capacity in fisheries and mariculture, maricultural production, diseases in mariculture, regional fisheries agreements, national laws and fisheries management.

Biodiversity Protection

This synthesis addresses the following topics: habitat conservation, vulnerable species, genetic diversity, introduced species, biodiversity regulations and regional biodiversity assessment. The regional synthesis (Wetlands International 2006) provides assessments of habitats and their status, the status of protected and vulnerable species, habitats of global significance, biodiversity conservation issues and biodiversity conservation actions in the region.

Reductions in Stress on the Ecosystem, Improvement of Water Quality and the Protection of Human Health

This synthesis addresses the following topics: stressors of the ecosystem, carrying capacity of the ecosystem, contaminant inputs, contaminant levels, contaminant fate and transport, harmful algal blooms and emerging disease, hot-spot analysis, emergency planning and preparedness and related legal and regulatory issues.

Institutional Development and Capacity-Building

This synthesis covers the following topics: stakeholder involvement, regional coordination, national institutions, financial instruments, data and information management and public awareness and participation.

By September 2006, draft regional assessments of the circumstances in the regions pertaining to each of the four technical components of the project had been completed in the form of "regional syntheses". This TDA is concretely built upon these regional syntheses that provide both the foundation and the bulk of the information required to complete the principal elements of the diagnostic analysis. Table 2 summarizes relevant subject areas and also shows which of the RWGs have an interest in the subject and which specific RWG has been designated as having the lead responsibility.

Table 2. Project Subject Areas and Regional Working Group (RWG) Responsibilities.

Subject Area*	Regional Working Group			
	Biodiversity	Ecosystem	Fisheries	Pollution
Decline in commercially important fishery species	x	x	X	
Mariculture	x	x	X	
Introduced species incl. mariculture and ballast water	X	x	x	
Species loss	X	x	x	
Changes in biodiversity	X	x	x	
Benthic habitat modification incl. beach erosion	X	x	x	x
Coastal habitat change and destruction	X	x	x	
Ecosystem structure & productivity	x	X	x	
Water quality (rivers, lakes and sea)	x	x	x	X
Eutrophication	x	x	x	X
Risks to human health				X

* The topic of biological carrying capacity of the Yellow Sea has been omitted from the list

x indicates that the RWG has an interest in the subject area.

X indicates that the designated RWG has primary or lead responsibility for the subject area.

The regional working groups are charged with the identification of environmental problems, the characterization of these problems, including the estimation of the scale of adverse effects, and the conduct of causal chain analyses for each problem in their respective areas of responsibility as depicted in Table 2.

Each of the Regional Working Groups has identified a variety of specific environmental problems within their areas of responsibility and these are identified and characterised in RWG meeting and synthesis reports. These problems are summarized in the following sub-sections under the heading of the responsible RWG.

Environmental Problems Relating to Pollution (Responsibilities of the RWG-P)

The following topics or problems have been identified as the responsibility of the Regional Working Group on Pollution:

Eutrophication, including the following sub-topics:

- Nitrogen enrichment;
- Phosphorus enrichment;
- Silicate depletion;
- Changed Si:N:P ratios;
- Oxygen depletion; and

- Phytoplankton blooms including red tides.

Contamination and its effects (i.e., pollution), including the following sub-topics:

- Faecal contamination;
- Heavy metal contamination;
- POPs contamination;
- PAH contamination; and
- Marine litter.

Increased risks to human health

(a) through seafood contamination; and

(b) through exposures to ontaminated water.

Environmental Problems Relating to Ecosystem (Responsibilities of the RWG-E)

The following topics or problems have been identified as the responsibility of the Regional Working Group on Ecosystem:

- Changes in ecosystem productivity at primary and secondary levels only; and
- Preservation of cold water habitat in the central Yellow Sea.

Environmental Problems Relating to Fisheries (Responsibilities of the RWG-F)

The following topics or problems have been identified as the responsibility of the Regional Working Group on Fisheries:

Over-exploitation of target wildfish species;

Unsustainable mariculture;

Risks to human health through the consumption of mariculture and aquaculture[7] products; and

Environmental contamination from mariculture and aquaculture, including the following sub-topics:

- Acidification of marine sediments;
- Nutrient releases;
- Pharmaceutical residue releases; and
- Bacteriological contamination of marine sediments.

Environmental Problems Relating to Biodiversity (Responsibilities of the RWG-B)

The following topics or problems have been identified as the responsibility of the Regional Working Group on Biodiversity:

- Reductions in benthic habitat in terms of area, quality and/or structure;
- Changes in benthic habitat structure;
- Loss of coastal wetlands and bird habitat
- Coverage of protected areas in the land coastal zone;
- Coverage of protected marine areas;
- Loss of biodiversity; and

7 In this document, the terms "mariculture", meaning the culturing of organisms in seawater, and "aquaculture", meaning the freshwater culturing of organisms, are distinguished.

- Effects on biodiversity caused by the introduction of xenobiotic species.

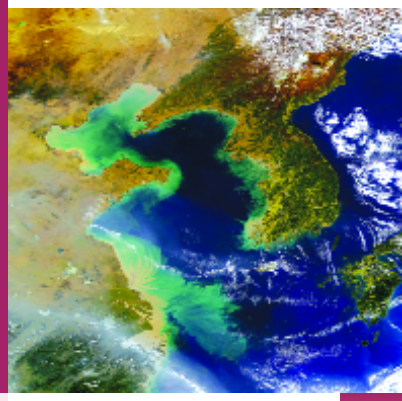
Other YSLME Regional Working Group Activities

There is one other Regional Working Group under the YSLME project. This is the Investment Regional Working Group that is responsible for examining ways of obtaining investments for remediation activities in the Yellow Sea area in preparation for the development of the YSLME Strategic Action Programme. There are two preparative activities being conducted by this working group that deserve mention here as they bear upon the quantification of benefits and detriment (i.e., adverse effects) and on the framework for governance in the Yellow Sea.

First, the work on valuation of environmental goods and services is in its early stages and will not be sufficiently advanced to be used for the purposes of including in the TDA the costs of adverse effects on the environment associated with contemporary problems in the Yellow Sea. Nevertheless this work should stand the project in good stead regarding the estimation of costs and benefits of potential interventions for inclusion in the SAP.

Second, the Investment RWG has undertaken studies of the governance regimes in the two countries currently involved in the project (People's Republic of China (PRC) and Republic of Korea (ROK)). This work is at a more advanced stage of development. Although the combined assessment of the governance regime in the area has not yet been completed, the two national reports (YSLME 2006a, b) provide sufficient background to be used for examining the context within which root causes identified through causal chain analyses need to be evaluated. Accordingly, these reports will be pertinent to, and will be used for, the analysis of options for intervention later in this TDA.

5. STATUS OF THE YELLOW SEA AND ENVIRONMENTAL ISSUES/PROBLEMS



The following sub-sections 5.1 to 5.4 itemise the environmental problems in each of the scientific project components. In large part, the following summaries leading to the identification of environmental problems in the Yellow Sea are taken from the four syntheses documents prepared by the Regional Working Groups on Pollution, Ecosystem, Biodiversity and Fisheries (YSLME 2006c, d, e, f). There is inevitably considerable crosstalk among the natural science elements of the project (i.e., commonalities among the issues considered by the individual Regional Working Groups). Nevertheless, for consistency and clarity of presentation, the disciplinary breakdown developed under the project has largely been preserved in the following summary of the status of the Yellow Sea and the identification of environmental problems.

5.1. Pollution

The Regional Working Group on Pollution first established the nature and priorities among the environmental concerns within its sphere of reference. These issues, their nature and their relative priorities are shown in Table 3.

This set of environmental problems is subjected to causal chain analysis in the next section of this report under the heading "pollution issues". It is necessary, however, to define the nature and adverse effects and/or threats posed by the perceived problems listed in Table 3.

Table 3. Types and Nature of Environmental Problems Relating to Pollution.

Environmental Issue	Nature of Issue	Priority of Issue[8]
1. Eutrophication	Category of Environmental Problems	1
Nitrogen (N) enrichment	Immediate Cause	1/1
Phosphorus (P) enrichment	Immediate Cause	Low
Silicate (Si) depletion	Immediate Cause	1/2
Changed Si:N:P ratios	Immediate Cause	1/2
Oxygen depletion	Consequence	N/A
Phytoplankton blooms including red tides	Consequence	N/A
2. Contaminants and their Effects	Category of Environmental Problems	2
Faecal contamination	Environmental Problem	2/1
Heavy metal contamination	Environmental Problem	2/5
POPs[9] contamination	Environmental Problem	2/4
PAH[10] contamination	Environmental Problem	2/2
Marine litter	Environmental Problem	2/3
3. Increased risks to human health	Category of Environmental Problems	3
- through seafood contamination	Environmental Problem	3/2
- through exposures to contaminated water	Environmental Problem	3/1

Eutrophication constitutes enhanced primary and/or secondary biological production and results primarily from the increased availability of dissolved inorganic nitrogen and phosphorus. This can arise as a result of increased delivery of nutrients in river flows or by the direct discharge of nutrient rich wastewater at the coast.

In the case of the Yellow Sea, the primary cause of increased eutrophication is an increased supply of dissolved nitrogen through riverine and wastewater discharge.

The adverse effects associated with eutrophication are excessive algal blooms that decrease water transparency and give rise to high concentrations of organic matter in surface waters often referred to as “red tides”. While it might appear that increased primary production would be beneficial to the Yellow Sea system, it results in reduced diversity among algal and zooplankton

8 “1” signifies the highest priority; “1/1” signifies the highest priority in category 1; N/A = not applicable

9 Persistent Organic Pollutants as defined by the Stockholm Convention 2001

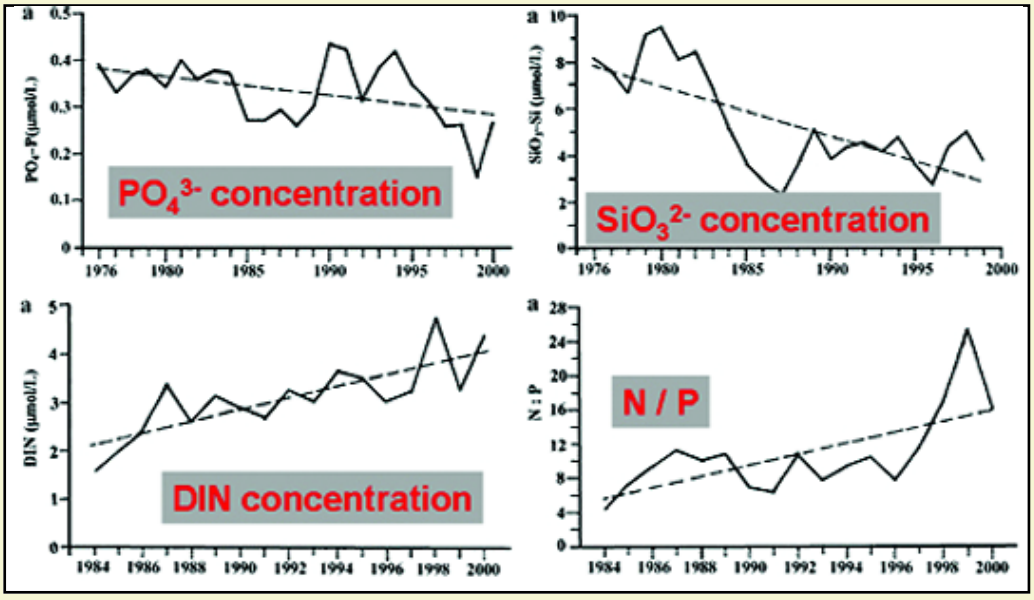
10 Polycyclic aromatic hydrocarbons

species and some of the dominant algae may be harmful to higher organisms such as fish. This is often compounded by substantial reductions in dissolved silicate that is essential for the production of silicious organisms such as diatoms. As dissolved silicate concentrations decrease there will be a tendency for primary organisms not dependent upon this nutrient, such as dinoflagellates, to predominate. Among the dinoflagellates, some organisms have either toxic or other properties, such as foaming, that can give rise to harmful effects on higher organisms, including humans, and cause foaming on beaches respectively. Irrespective of the nature of the organisms involved in algal blooms, unless the excess organic matter is utilized in the euphotic zone (the surface layer bounded by the limit to which solar energy, or light, penetrates), the organic matter can descend below the euphotic zone before decaying. This, in turn, places an increased demand for oxygen to sustain the decay of the organic material thereby reducing the levels of dissolved oxygen available to sustain living aerobic organisms in deeper waters.

Temporal trends in dissolved nitrogen, phosphate and silicate in the Yellow Sea are depicted in Figure 6 as reproduced in YSLME (2006c). This figure shows a trend of increasing dissolved inorganic nitrogen (DIN) and corresponding declines in the concentrations of phosphate and silicate in the Yellow Sea resulting in an increasing N/P ratio and reduced silicate that would be consonant with conditions under which blooms of dinoflagellates would be expected to become more frequent.

Figure 6. Temporal Trends in Annual Mean Nutrient Concentrations and N/P Ratio in the Yellow Sea.

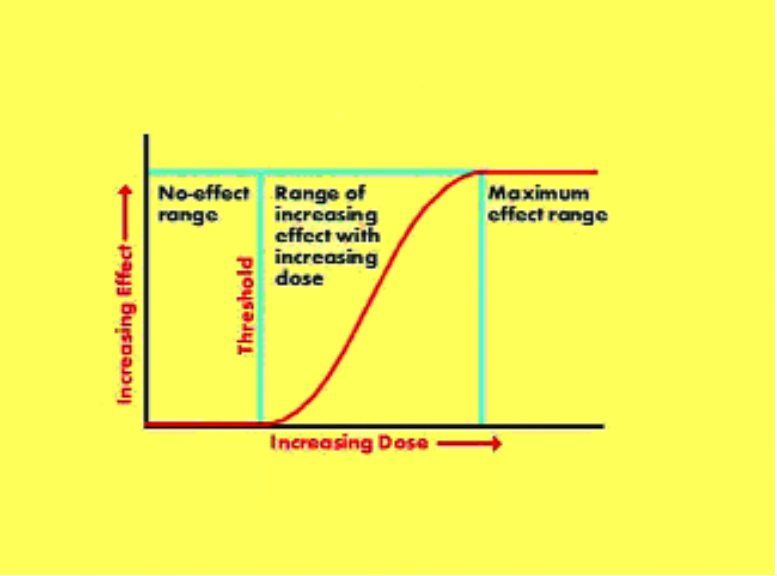
(As reproduced in YSLME 2006c)



The topic contaminants and their effects covers contamination of the marine environment by substances of anthropogenic (human and industrial) origin that enter the marine environment largely through the disposal of household and industrial wastes to rivers and the sea. Some contaminants, especially the more volatile substances such as some hydrocarbons, can also enter by way of atmospheric transport and wet and dry deposition. The presence of contaminants in the marine environment per se does not necessarily give rise to adverse effects. Such contaminants have been present throughout the human era and it is only when they are present at sufficiently high concentrations in the marine environment that they give rise to adverse effects. Nitrogen is one such contaminant that was discussed in the previous section. At normal concentrations, this substance is essential for life; it is only when it is present at excessive concentrations that adverse effects ensue such as those described above. Such a situation applies to most biologically essential elements and compounds. For non-essential elements and compounds, there will generally be a threshold for the onset of adverse effects unless the chemical is assumed to have stochastic effects in which the probability of an effect is proportional to exposure or dose. For chemicals not giving rise to stochastic effects, the changes in the nature of biological effects as a function of exposure (or dose) are shown by a dose-response curve that takes the general form shown in Box 2.

The list of environmental problems in this category identified by the RWG-P comprise faecal substances, heavy metals, persistent organic pollutants (i.e., POPs as defined under the Stockholm Convention (UNEP, 2001)), polycyclic aromatic hydrocarbons (PAHs) and marine litter. Faecal pathogens are contained in human wastes that enter the marine environment primarily through sewage discharges. Morbidity in humans can arise when exposures to faecal pathogens occur, either through direct contact with contaminated water or the consumption of contaminated seafood. Such morbidity includes stomach ailments commonly experienced by tourists. However, it can also include much more serious ailments such as typhoid and dysentery that can be fatal. Thus, the presence of such substances in coastal waters constitutes a hazard to human health that can result in reduced tourism opportunities and income as well as reduced value of seafood.

BOX 2
Generalized Dose-Response Relationship



In this diagram, no effect is evident when the quantity of dose is between zero and the 'threshold'. This is because some biochemical or physiological defence system within the body helps prevent any adverse effect from occurring. In fact, many organisms show a benefit from exposure to some chemicals at very low doses. This result may come from a 'challenge' to the organism from the chemical to which it responds positively, or may result because the chemical may be important for its life's functions (endogenous chemical). At the "threshold" line in the above diagram, the defence system is fully utilised or saturated and may be starting to become overwhelmed, leading to the beginning of adverse health effects.

Contamination of the marine environment with some heavy metals is of concern primarily because of increased risks to human health. However, there are relatively few metals for which the primary pathway of exposure is likely to be through the marine environment. There have been exceptions to this generality in the past, most notably the appearance of Minimata disease in Japan in the 1960s that was caused by mercury (Hg) contamination associated with an industrial discharge. However, currently, the metals of most concern are lead (Pb), copper (Cu) and mercury (Hg) primarily derived from aggregate industrial activities. The primary human exposures to lead have historically been derived from leaded fuel combustion and lead-based paints. Blood lead levels are usually assessed for human health protection purposes, especially in children and pregnant women, and in most jurisdictions controls on lead, such as the transition to lead-free paints and

lead-free gasoline, have resulted in reduced exposures. While mercury contamination continues to be an issue of public health concern, it is only occasionally one that is connected to marine pathways of exposure. In these cases, primary concern is related to the consumption of long-lived fish such as swordfish that have high fatty tissue concentrations of mercury in methylated form. Concerns over copper contamination differ from those of lead and mercury. Copper is an essential element but can, in some areas, off Taiwan for example, be found in markedly elevated concentrations in seafoods due to metal mining and refining activities. In general, however, concerns about copper relate primarily to the potential for adverse effects on biological productivity.

Contamination of the marine environment with the 12 classes of so-called "Persistent Organic Pollutants" (POPs) (see Box 3) covered by the Stockholm Convention does not generally entail severe local damage or threat. The concerns regarding POPs are global exposures to these substances that involve increased health risks to humans and/or animals. Nevertheless, the incorporation of these persistent lipophyllic[11] substances in seafoods is a matter of concern. Accordingly, the dissemination of POPs needs to be minimized or eliminated and human exposures to these substances through seafood consumption need to be monitored to ensure adequate levels of public health protection. In large part, measures to reduce the release of POPs to the environment will be covered by the National Action Plans prepared by Contracting Parties to the Stockholm Convention that include the PRC and ROK (and, incidentally, the DPRK).

11 Lipophyllic substances have an affinity for fatty tissues.

BOX 3

Persistent Organic Pollutants (POPs) Included Under Annexes to the Stockholm Convention 2001

Annex A Elimination

Aldrin
Chlordane
Dieldrin
Endrin
Heptachlor
Hexachlorobenzene (HCB)
Mirex
Toxaphene
Polychlorinated Biphenyls (PCBs)

Annex B Restriction

1,1,1-Trichloro-2,2-bis(4-Chlorophenyl)ethane (DDT)

Annex C Unintentional Production

Polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDD/PCDF)
Hexachlorobenzene (HCB)
Polychlorinated Biphenyls (PCBs)

Contamination by polycyclic aromatic hydrocarbons (PAHs), by comparison, is likely to be a more localized issue. PAHs are derived primarily from petroleum refinery operations, burning and incineration of solid wastes and from metallurgical refining activities. This class of compounds is of concern primarily from the perspectives of human and animal health because the substances can be mutagenic (causing hereditary mutations) and carcinogenic (causing cancer).

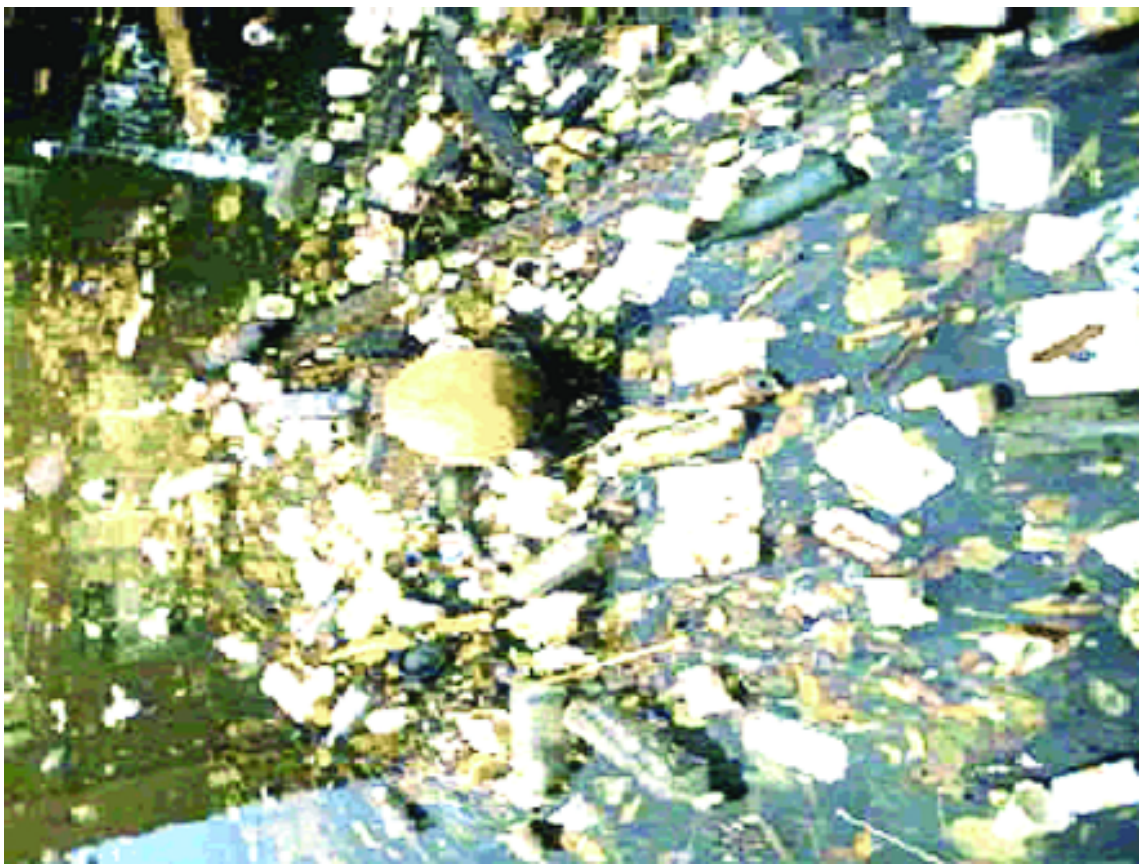
The final environmental issue in the list identified by the RWG-P is marine litter. This is another global problem on account of the diversity of sources of floating, stranded and submerged debris in the global ocean. Marine litter interferes with amenities, such as beaches; many countries have to spend large amounts of effort and expenditure on cleaning to render beaches fit for recreational activities (See Figure 7). Both floating and submerged litter can cause damage to fishing gear and boats

through the fouling of equipment and propellers. In rare cases, even structural damage to small and medium sized coastal and recreational vessels can occur.

There is a growing international consensus that marine litter is a major global problem worthy of increased attention.

Unfortunately, there is no concrete information regarding such forms of damage and costs in the Yellow Sea on which to confirm the priority assignment by the RWG-P.

Figure 7. Marine Litter.



5.2. Ecosystem (primary and secondary production and benthos)

At its third meeting, the Regional Working Group on the Ecosystem Component undertook an exercise to identify environmental problems within its area of responsibility. These problems are itemized in Table 4.

Table 4. Types and Nature of Environmental Problems Relating to the Ecosystem Component.

Environmental Issue	Nature of Issue	Priority
Change in biomass or abundance	Environmental Problem	3
Change in species composition	Environmental Problem	2
Increased frequency of harmful algal blooms (HABs)	Environmental Problem	1
Loss of benthic habitat in coastal areas	Environmental Problem	Referred to RWG-B

This set of environmental problems is subjected to causal chain analysis in the next main section of this report under the heading "*ecosystem problems*". The following text provides a description of the nature and adverse effects and/or threats posed by the perceived problems listed in Table 4.

Under the heading "*change in biomass or abundance*" the RWG-E has first listed "*Increase in zooplankton > 330 μm zooplankton in the Korean area of the Yellow Sea*" and "*Decrease in zooplankton > 505 μm and phytoplankton > 77 μm in the Chinese area of the Yellow Sea*". The concern here is that these changes, although incoherent, are evidence of changes in the composition of both phytoplankton and zooplankton communities in the Yellow Sea. The consequences of such changes in community composition are changes in the food web and threats to the food supplies for living marine resources at higher trophic levels. The decreases in phytoplankton >77μm in the Chinese area of the Yellow Sea could also result in a reduced capacity for carbon fixation in the region and a change in carbon fluxes over a large area. Similarly, such reductions could also result in reduced production of dimethyl sulphide that plays a significant role in cloud formation, thus having an influence on both regional and global climatic conditions. Under the same category the RWG-E has also defined a "*Shift in peak in seasonal pattern of zooplankton biomass abundance in the Korean area of the Yellow Sea*". This reflects similar evidence of zooplanktonic community

changes that could have an adverse effect on the food supplies for higher trophic level organisms. It must be remembered that phytoplankton and zooplankton constitute the foundation for the entire marine food web that ultimately provides the basis for the sustenance of all marine species, including commercial wildfish and other exploited species. Changes in primary and secondary production, both in terms of the rates of production and species diversity, will inevitably have consequences at higher levels in the marine organism community but contemporary knowledge of food web dynamics does not allow for reliable prediction of the consequences at higher trophic levels.

Under the heading "*Change in species composition*" the RWG-E has listed "*Change in dominant groups of zooplankton (Korea)*", "Changed ratio of diatoms to dinoflagellates (China)", "*Jellyfish blooms*" and "*Change in benthic species composition and dominant species*". The first two of these issues are of concern because they reflect changes in food web dynamics that can affect organisms at higher trophic levels. The change in phytoplankton species from diatoms to dinoflagellates could either be a corresponding response to changes in predation or, more likely, a response to an abundance of dissolved nitrogen and phosphorus accompanied by dissolved silicate impoverishment. The concern here is that the majority of toxic algae and those that cause adverse effects on other marine organisms are in the dinoflagellate class of phytoplankton. Thus, it is likely that the shift from diatoms to flagellates is a response to much reduced silicate concentrations in relation to the other nutrients. This has occurred elsewhere, in the eastern North Sea for example, and has occasionally given rise to a preponderance of foaming algae that caused aesthetic problems for beach users.

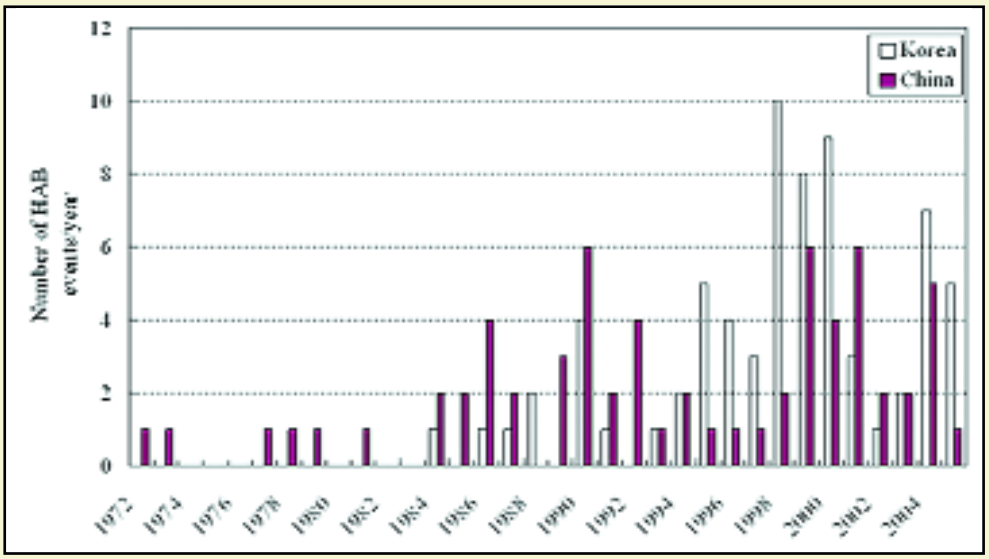
There has been a significant increase in the abundance of jellyfish within the Yellow Sea in recent years. Jellyfish cause interference with fishing activities, the clogging of sea water intakes and pose threats of stinging to sea bathers. The increased presence of jellyfish is also a reflection of changes in primary and secondary productivity in the system and alterations to the food web of the Yellow Sea.

The change in benthic species composition and the dominant benthos in parts of the Yellow Sea signify a reduction in benthic biodiversity. Such changes will be a response both to changes in the food web dynamics and the composition of bottom sediments. The concern here is that such changes will reduce the availability of both benthic and demersal fishing resources in the Yellow Sea but currently there exist insufficient data to quantify such losses.

Under the heading of the increased frequency of harmful algal blooms,

the RWG-E has noted that there has been a significant increase in the annual incidence of intense algal blooms (see Figure 8[12]). Such blooms can cause increased mortality of mariculture stocks, kills of wild fish thereby reducing fishery yields, and increased risks to seafood consumers through the incorporation of natural toxins into exploited marine organisms.

Figure 8. Frequency of Intense Algal Blooms.



While the appearance of the various problems listed above may occur in both national and international waters, concerns about changes in primary and secondary production in areas of the Yellow Sea are intrinsically transboundary because of the oceanographic continuity of the system.

Finally, the RWG-E has indicated a concern regarding the loss of benthic habitat in coastal areas, especially on the Chinese side of the Yellow Sea. This results from the massive expansion of mariculture and from the substantially increased discharges of wastes to coastal areas. This issue is, however, addressed under habitat issues in the biodiversity section, 5.4.

12 Despite the label "HAB" (Harmful Algal Blooms) on the ordinate axis, this figure depicts intense algal blooms defined as exceeding a minimum cell density (cells/cm3) or causing discoloration of water (i.e., red tides). The Korean data may partially reflect increased monitoring since 1995.

5.3. Fisheries

The Regional Working Group on Fisheries (RWG-F) has the responsibility of addressing both capture fisheries, mariculture (i.e., sea farming of organisms) and inland aquaculture (i.e., freshwater farming of organisms). Based on the regional synthesis for fisheries (YSLME 2006e), the problems listed in Table 5 have been identified.

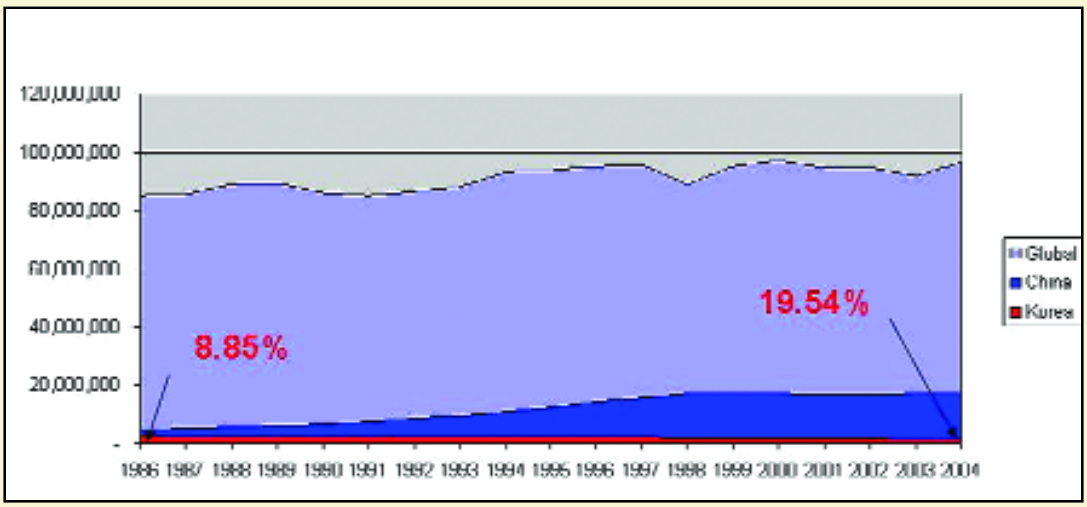
Table 5. Types and Nature of Environmental Problems Relating to the Fisheries Component.

Environmental Issue	Nature of Issue	Priority
Decline in landings of many traditional commercially-important species and increased landing of low value species (including changes in dominant species)	Environmental problem and threat	1
Unsustainable maricultural practices	Environmental problem and threat	2

The following text provides a description of the nature and adverse effects and/or threats posed by the perceived problems listed in Table 5.

A context for a discussion of fisheries in the Yellow Sea is provided by the increasing scale of capture fisheries landings in China and Korea as a proportion of the global total as shown in Figure 9.

Figure 9. Capture Fisheries Landings in China and Korea in Relation to Global (tonnes).



The first problem listed in Table 5 is "the decline in landings of many traditional commercially-important species and increased landings of low value species". This trend is believed to relate directly to concerns about overfishing and the effects of overexploitation of fish stocks in the Yellow Sea. There have been concerns about the overexploitation of wildfish stocks in the Yellow Sea for several years. The issue has been raised in several assessments including the preliminary TDA conducted in the PDF-B stage of the YSLME project and the Global International Waters Assessment of the Yellow Sea (GIWA 2005). The initial framework for the analysis of the status of the Yellow Sea fishery is provided by the regional catch statistics for China and Korea shown in Tables 6 and 7 respectively (YSLME 2006e)[13].

13 These catch statistics are based on landings in provinces bordering the Yellow Sea. As the borders of two provinces extend to other sea coasts, some catches from adjacent sea areas are included in these figures.

Table 6. Total catch of commercially important species in China 1986-2004 (tonnes)

Year	Small Yellow Croaker	Spanish Mackerel	Anchovy	Chub Mackerel	Largehead Hairtail	Pacific Herring	Sandance	Acetes	Fleshy Prawn	Squid	Total
1986	13,409	54,843	0	40,465	75,809	1,729	0	70,678	17,270	22,200	296,403
1987	16,806	61,047	0	51,111	73,383	3,354	0	62,598	9,932	19,869	298,100
1988	17,686	74,494	0	67,425	73,883	2,408	0	73,772	18,014	28,736	356,418
1989	12,939	75,743	20,035	58,738	85,256	798	0	82,409	7,952	16,289	360,159
1990	18,648	132,290	43,706	43,304	95,001	834	0	102,928	14,717	16,690	468,118
1991	36,412	115,508	68,495	64,031	111,770	1,065	0	99,937	10,377	14,339	521,934
1992	45,624	68,260	162,273	71,440	120,246	89	0	64,298	9,942	10,292	552,464
1993	58,717	66,073	272,923	75,885	111,033	0	0	107,007	5,946	15,740	713,324
1994	70,502	104,848	336,884	98,062	164,247	98	0	119,686	4,731	17,545	916,603
1995	110,620	99,448	426,326	164,598	203,118	564	0	172,829	4,610	31,915	1,214,028
1996	94,633	146,499	629,414	127,157	172,427	7	0	180,850	4,867	36,253	1,392,107
1997	76,129	178,145	1,037,682	131,971	138,673	365	0	197,234	5,889	39,134	1,805,222
1998	109,064	291,586	1,008,969	145,516	196,182	67	0	291,882	6,460	33,607	2,083,333
1999	141,529	284,713	893,493	158,542	219,317	54	0	256,818	7,687	33,338	1,995,491
2000	163,841	246,890	933,234	140,936	216,450	104	0	272,854	8,062	72,757	2,055,128
2001	155,088	227,583	1,050,178	133,343	209,337	-	0	275,302	6,536	40,323	2,097,690
2002	163,302	264,336	1,022,188	158,008	245,316	-	0	253,511	6,937	43,679	2,157,277
2003	155,062	257,637	1,060,687	156,844	237,960	-	195,216	235,500	7,114	26,974	2,332,994
2004	187,309	273,699	878,512	136,159	303,321	-	177,213	293,820	7,651	29,982	2,287,666
Mean	86,701	159,139	518,158	106,502	160,670	-	19,602	169,153	8,668	28,930	1,257,522

Table 7. Total catch of commercially important species in RO Korea 1986-2004 (tonnes)

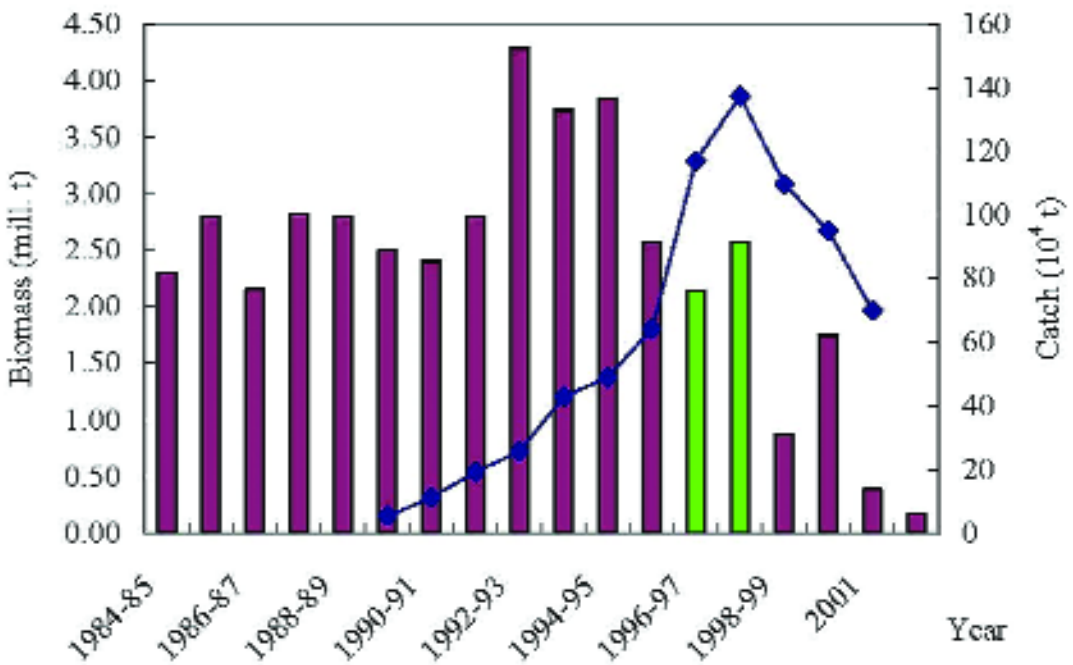
Year	Small Yellow Croaker	Spanish Mackerel	Anchovy	Chub Mackerel	Largehead Hairtail	Pacific Herring	Sandance	Aceles	Fleshy Prawn	Squid	Total
1986	2,601	1,862	28,007	2,466	50,382	17	0	11,375	964	30,404	128,077
1987	6,243	1,685	30,519	3,798	56,940	14	0	13,712	437	28,646	141,992
1988	4,777	856	21,472	5,049	48,984	2	0	8,417	517	22,466	112537
1989	5,404	1,382	19,831	4,379	48,374	14	0	16,192	775	15,029	111,379
1990	9,369	1,643	21,101	1,635	47,201	12	1	17,627	833	14,957	114,378
1991	16,182	1,101	27,108	1,107	45,275	3,531	10	13,936	972	14,903	124,123
1992	13,887	869	26,046	3,187	35,515	1	101	14,940	954	10,054	105,552
1993	9,616	648	38,701	6,933	24,065	0	91	20,411	764	7,881	109,127
1994	14,189	801	29,747	7,018	34,145	0	280	14,111	1,078	7,209	108,575
1995	7,713	617	32,486	6,339	22,430	0	1,334	13,609	1,227	5,014	90,767
1996	8,204	228	50,392	12,641	14,671	0	1,054	12,827	1,018	4,903	105,936
1997	7,559	343	42,900	2,292	11,525	3	896	10,576	1,562	5,484	83,138
1998	4,709	627	41,422	2,732	13,378	9	0	11,916	974	9,874	85,639
1999	4,600	543	53,533	2,471	7,314	0	6	16,309	738	8,295	93,807
2000	6,266	739	48,446	2,587	6,846	0	11,956	10,662	1,044	3,637	92,181
2001	2,595	930	49,427	6,684	5,285	2	328	8,632	420	6,182	80,483
2002	2,988	988	53,808	2,831	2,919	9	2,118	4,659	207	6,816	77,341
2003	2,462	1,035	35,899	1,459	4,910	0	2,003	8,530	123	6,683	63,102
2004	6,110	1,002	41,477	3,330	9,195	2	222	5,182	702	8,065	75,283
Mean	7,130	942	36,438	4,154	25,755	190	1,074	12,296	807	11,395	100,180

Initial examination of the figures in these tables reveals three observations: the dominance of the overall fisheries catch by China for all species, the apparent decline of the Pacific herring and the rapid growth of the anchovy fishery in China in the 1990s.

In the early 1970s, the main target of the pelagic fisheries was Pacific herring (*Clupea pallasi*) with the peak catch of 180,000 tonnes in 1972. The catch has decreased continuously since then and overfishing of this species has undoubtedly contributed to the decline in this fishery with climatic change also playing a role.

Annual landings of anchovy have increased due to the increased abundance of this species and the expanded fishing effort. The annual landing of anchovy increased from 20,000 tons in 1989 to 640,000 tonnes in 1996. More than 1 million tonnes were caught in 1997 and 1998, making it the highest landing single species fishery in China. However, these catches greatly exceeded the 0.6 million tonnes maximum sustainable yield (MSY) (GIWA, 2005) and, based on acoustic surveys, recruitment has sharply declined to about 0.2-0.3 million tonnes. The dominant Chinese anchovy catch and biomass trends are shown in Figure 10 (YSLME 2006e).

Figure 10. Annual Japanese anchovy biomass (bars) and Chinese landings (line)



The trends in Figure 10 tend to confirm that overfishing has depleted the stock of Japanese anchovy in the Yellow Sea. However, in respect to the other marine capture fisheries, the situation appears roughly stable despite some short-term fluctuations that may reflect natural recruitment cycles and climatic changes. The Yellow Sea overall remains a productive fisheries area yielding over 2.3 million tonnes, or over 2 tonnes per km2, of wildfish during the most recent years. This productivity can be compared with approximately 6 tonnes per km2 obtained through capture fisheries in the North Sea that has comparable bathymetry and the yield of approximately 1,000,000 tonnes over an area of 2.5 million km2 or 0.4 tonnes per km2 in the Mediterranean Sea that has a far larger bathymetric range.

A further basis for analysis is the catch per unit fishing effort (CPUE). The CPUE on the basis of total fishing vessels, including fishing efforts from powered and non-powered vessels, increased significantly from 3,900 kg in 1986 to 17,200 kg in 2004. The CPUE on the basis of total gross tonnage and kilowatt (kW) effort maintained the same upward trend from 1992 to 1998. Recent values for CPUE on any basis from 2001 to 2004 remained essentially unchanged. Thus, the primary fisheries overexploitation issues are in respect to Pacific herring and Japanese anchovy.

Included as a parenthetic clause under the first problem listed by the RWG-F is "Changes in dominant species". This is also believed to reflect a response to overexploitation of the dominant stocks as a result of increased fishing effort. The species diversity of the migratory resources seems less than that of the locally resident resources but their biomasses are much more abundant. The commercial catches in the Yellow Sea are mainly of migratory species and this intrinsically makes the nature of the issue a transboundary one.

The other economically important species in the Yellow Sea and the Bohai Sea are small yellow croaker *Larimichthys polyactis*, largehead hairtail *Trichiurus lepturus* and fleshy prawn *Fenneropenaeus chinensis*. A dramatic change has occurred in the fishery for pelagic fish with the growth in the Japanese anchovy *Engraulis japonicus* fishery in the Yellow Sea.

Up to the 1980s, there was no anchovy fishery in the Yellow Sea but, in 1997 and 1998, the anchovy catch exceeded 1 million tonnes, which was the largest landing for any single species.

In the Korean fishery during the 1990s, anchovy was the most dominant species, representing 37.5% of the total catch followed by largehead hairtail at 23.8%, acetes at 14.4%, small yellow croaker at 9.2%, squid at 8.5%, chub mackerel at 4.7%, fleshy prawn at 1.0% and Spanish

mackerel at 0.7%. In the 2000s, anchovy was again the most dominant species, representing 61.6% of the total catch followed by acetes at 10.0%, squid at 8.6%, largehead hairtail at 7.9%, small yellow croaker at 5.5%, chub mackerel at 4.6%, Spanish mackerel at 1.3% and fleshy prawn at 0.7%. Thus, in Korea, there has been a shift in the dominant species between the 1980s and the first decade of 2000.

The catch ratio of largehead hairtail, which was the largest in the 1980s, decreased gradually after 1990 while the catch ratio of anchovy became the largest over the same period. In China, the catch of anchovy increased massively from zero prior to 1989 to more than 1 million tonnes by 2001. Similarly, the catch of small yellow croaker rose from about 15,000 tonnes per year in the 1980s to more than 150,000 tonnes per year after 1999. The catches of acetes, largehead hairtail, Spanish mackerel, chub mackerel, fleshy prawn and squid have been relatively stable. The small Pacific salmon catch ended in 2000 while the sandlance catch has gone from zero before 2002 to 195,000 and 179,000 tonnes in 2003 and 2004 respectively.

There is therefore evidence of changes in catch species in the entire Yellow Sea, such as the growth of the anchovy catch and the lowered catch of the largehead hairtail. While the overall yield from capture fisheries in the Yellow Sea as a whole appears to be fairly constant (Figure 11), there is evidence of change in the comparative yields of different species that warrant the concern expressed (Figure 12).

Figure 11. Temporal Trend for the Catch from the Yellow Sea of 10 Commercially-Important Species, 1986-2004.

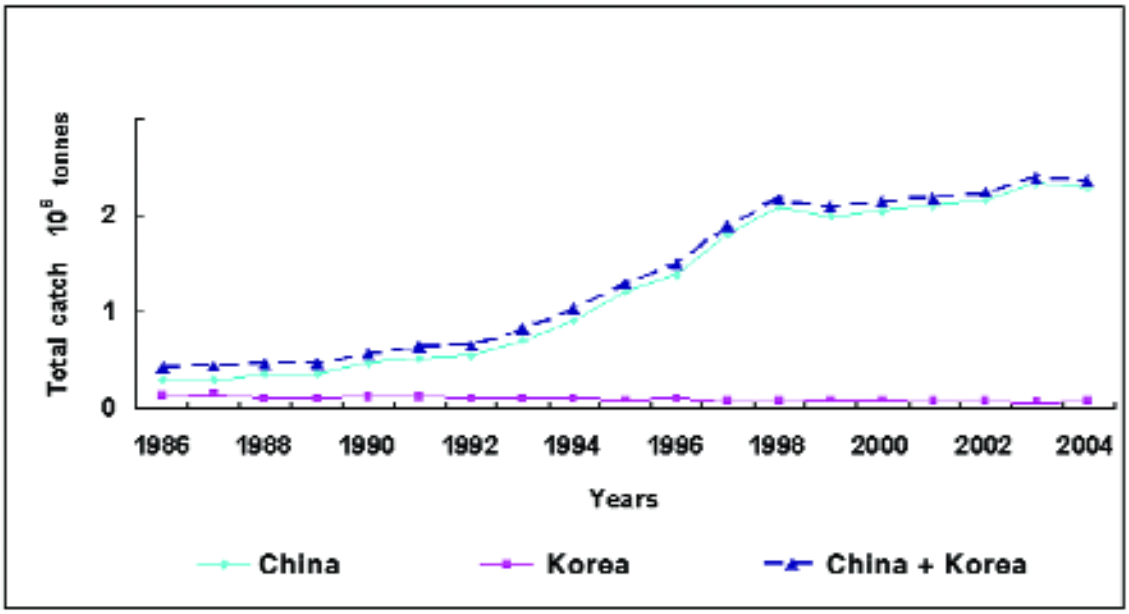
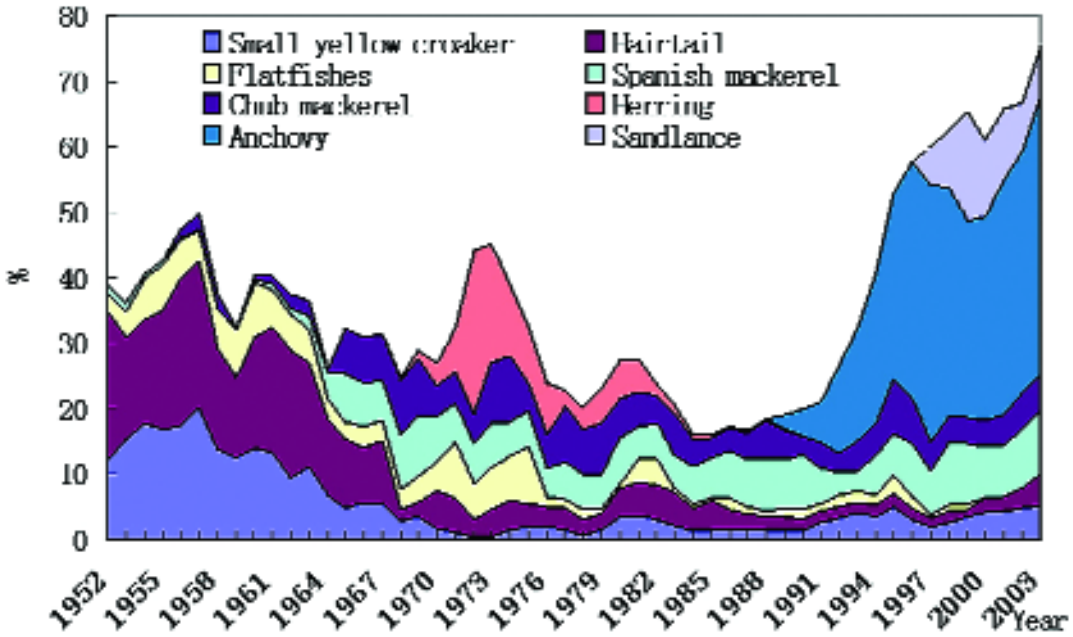


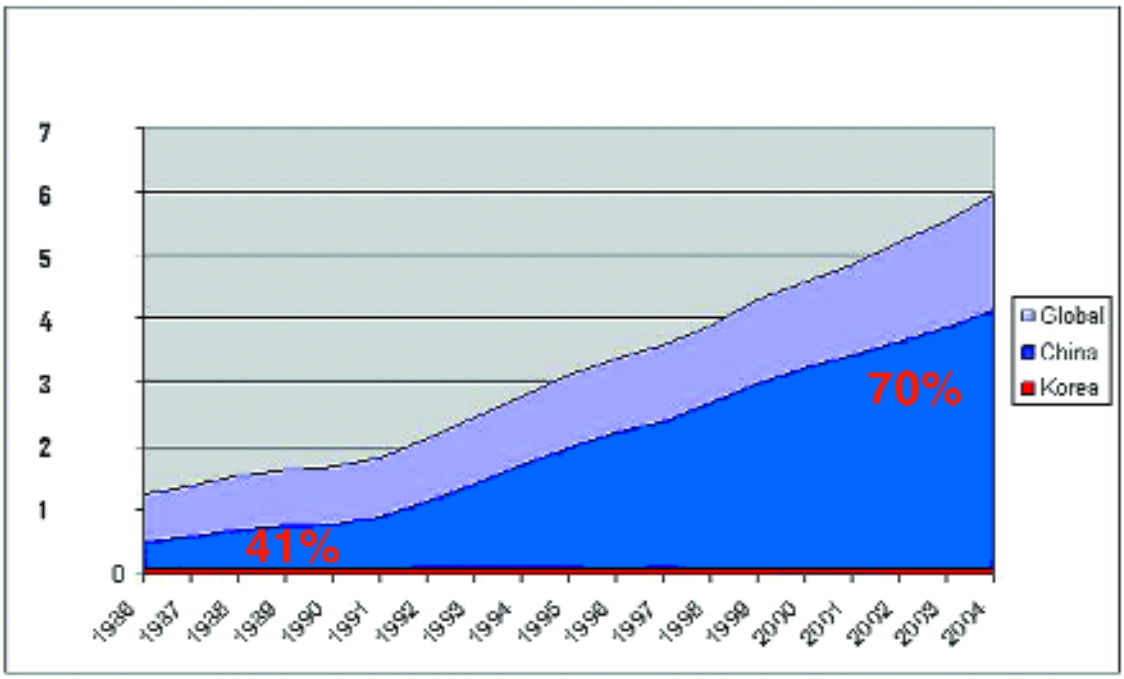
Figure 12. Percentage Yield of 8 Commercially-Important Wild Fish Species



The second most important issue identified by the RWG-F is the "Rapid expansion of mariculture (in some areas by a factor 7) without adequate understanding of the consequences". Mariculture in China has a long history and dates back to the Song Dynasty about 1,000 years ago when a seaweed

called glueweed, *Gloiopeltis furcata*, was harvested by a simple rock-cleaning method in Jinmen near Xiamen, Fujian Province. The growth in culturing of aquatic organisms for food production in the region is reflected in the scale of combined mariculture and inland aquaculture in China and Korea as a proportion of global production as shown in Figure 13.

Figure 13. Growth of Combined Mariculture and Aquaculture Production in China and Korea in Comparison with Global (Millions of tonnes)



Over the period 1995 to 1997, Yellow Sea maricultural production increased rapidly from 400 thousand tonnes/year to just less than 4 million tonnes/per year. Subsequently, there has been continued, but less spectacular, growth to over 6 million tonnes in 2004. The gross annual Yellow Sea mariculture production for the years 1995 to 2004 and the annual breakdown among finfish, crustaceans, molluscs and seaweeds is shown in Table 8 (Note: the numbers are taken directly from the Fisheries Synthesis Report (YSLME 2006e) without regard to the significance of the figures).

Table 8. Total catch of commercially important species in RO Korea 1986-2004 (tonnes)

Species	Year									
	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Finfish	975	33,942	37,931	49,364	54,759	70,752	98,755	155,310	135,725	159,041
Crustacea	7,443	38,618	57,000	64,148	72,997	85,403	110,426	131,293	135,202	154,340
Shellfish	199,128	2,019,783	3,032,230	3,037,281	3,547,837	3,845,123	4,171,174	4,495,842	4,610,421	4,807,310
Seaweeds	193,469	788,494	803,037	817,778	885,521	914,710	900,857	964,693	1,004,017	1,077,019
Other	858	1,213	2,717	5,001	9,156	15,172	17,339	34,467	92,452	51,923
Total	401,872	2,882,050	3,932,915	3,970,601	4,567,270	4,931,158	5,298,550	5,781,804	5,974,817	6,246,633

As can be seen from Table 8, the growth of mariculture has occurred for all classes of product but shellfish and seaweeds represent the dominant proportions of the gross production. This increased production needs first to be examined in the context of the increased marine area devoted to mariculture to examine if, and how, farming densities have changed.

Over the period 1995 to 2004, the area devoted to mariculture on the west coast of Korea has increased from 32,000 ha to 56,000 ha while mariculture production has remained essentially unchanged at 200,000 tonnes, apart from lowering to an average of 150,000 tonnes in the period 1998 to 2002. This suggests that, while the farmed area off the west coast of Korea has increased, the density of cultured organisms has decreased.

Unfortunately, the necessary breakdown of Chinese national statistics for the Yellow Sea coast has not been made available. However, if the national statistics are used as a guide to farm densities, these show that the area devoted to mariculture has increased from 400,000 ha to 1,000,000 ha over the same period. If the low production year of 1995 is excluded, the total mariculture production from the Yellow Sea in China has increased by a factor of 2.25, which is slightly less than the increase in area devoted to mariculture. This suggests that the farm density of cultured organisms has probably not changed substantially. Thus, any problem associated with excessive maricultural production is likely either due to the increased coastal area devoted to mariculture or to the increased proximity of

farms. In the former case, the concern would relate to the capacity of coastal areas, based on their flushing characteristics and the effects on sediment in-fauna and epifauna of increased organic matter sedimentation, to accommodate increased mariculture. In the latter case, the concem would be related to the transmission of disease among farms. However, in both cases, the problem would be a domestic one. The only case in which these problems could become transboundary is if diseases were spread to widely dispersed or migratory wildfish.

5.4. Biodiversity

The Regional Working Group on Biodiversity (RWG-B) has the responsibility of addressing changes and threats to biodiversity in the Yellow Sea, including habitat change. Based on the regional synthesis for biodiversity (YSLME 2006f), the problems listed in Table 9 have been identified. The following text provides a description of the nature and adverse effects and/or threats posed by the perceived biodiversity problems listed in this table.

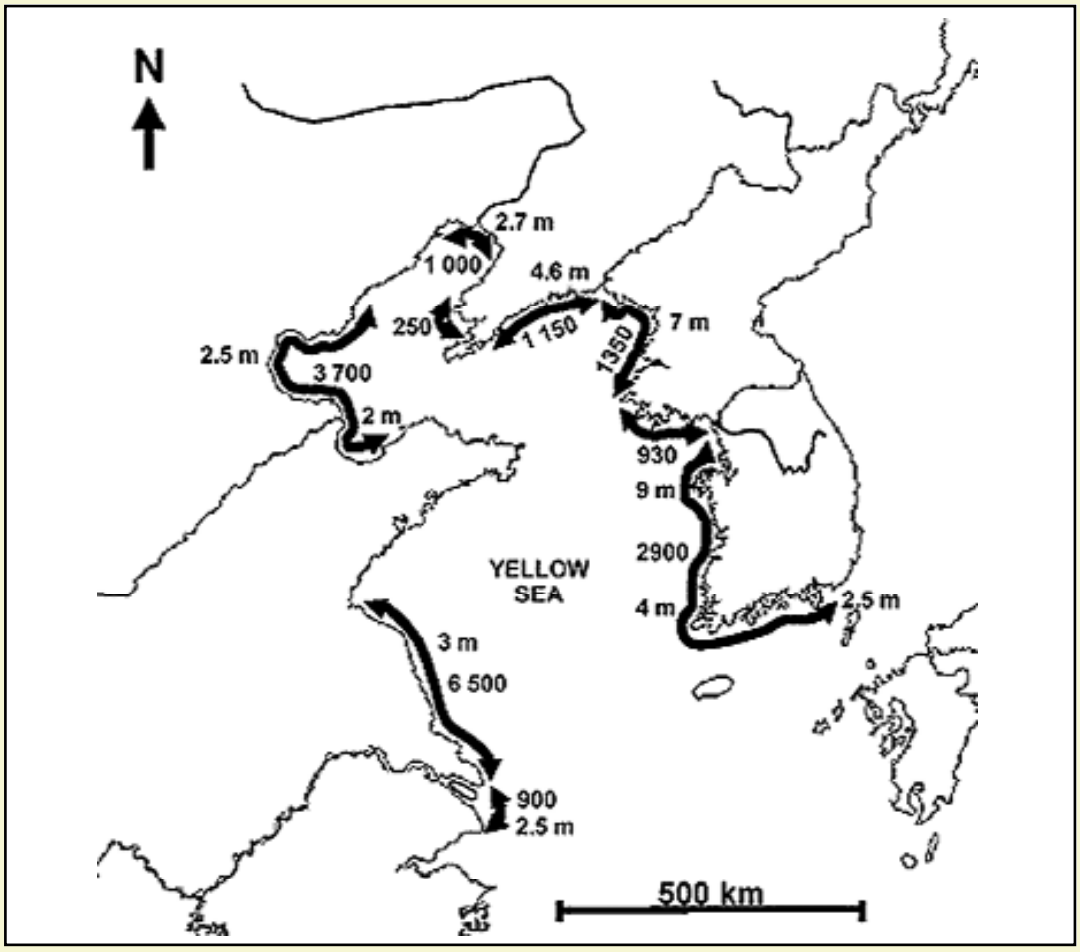
The first problem listed is "Coastal habitat loss and degradation". The Chinese coast contains extensive stretches of tidal flats separated by the rocky regions of the Shandong and Liaoning Peninsulas and north-west Liaodong Wan. In addition, deltas occur at the mouths of the Changjiang, Huang He, Luan He and Liao He. The west coast of the ROK consists of extensive tidal flats in broad estuaries in the north and surrounding islands in the southwest. The south coast has deep bays with large mudflats. The main tidal flat distribution, with regional areas in km2 and average tidal ranges for a number of coastal areas of the Yellow Sea, is shown in Figure 14 (after Barter, 2002).

Table 9. Types and Nature of Environmental Problems Relating to the Biodiversity Component

Environmental Issue	Nature of Issue	Priority
Habitat loss and degradation	Biodiversity issue	1
Pollution	Biodiversity issue	2
Changes in river discharge	Biodiversity issue	3
Overexploitation of marine and coastal living resources	Biodiversity issue	4
Introduction of xenobiotic (alien) species	Biodiversity issue	5
Decline of endemic species	Biodiversity issue	6

Figure 14. Tidal Mudflats on the Periphery of the Yellow Sea.

Areas in km² and tidal ranges in metres



The total area of intertidal flats in the Yellow Sea, including the Changjiang Estuary and the south coast of the ROK, is about 20,000 km². This includes 1,350 km² in numerous bays and estuaries around the Shandong Peninsula. The intertidal areas of the northern Yellow Sea are frozen during winter and are unlikely to support shorebirds at that time of the year. Air and water temperatures rise quickly from March onwards and the mudflats then become available to shorebirds during the northward migration period. The total area of the marshlands has decreased by approximately 30% during the last 30 years. The consequence has been reduced habitat for indigenous waterfowl and migratory birds.

Heavy erosion has occurred to about two-thirds of the sandy foreshores due primarily to sand mining of beaches and

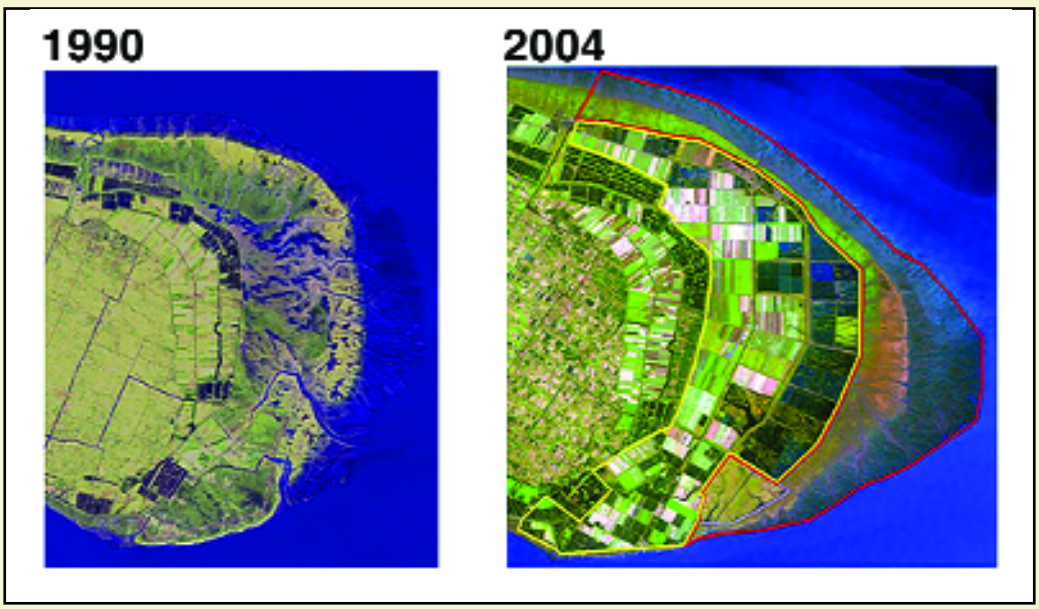
extensive agricultural activities along coastal plains. Sand and gravel substrates used to be important habitats for an endangered species, the lancelet (*Branchiostoma belcherii*). Currently, lancelets could not be found in such habitats that are losing their ecological function. Species community structure and abundance of the aquatic life in these sandy shores have greatly altered. Species, such as Nereidae, that were also previously found in these habitats, have now become rare and, consequently, biodiversity has been significantly reduced.

More than 30% of the mud foreshores of the Yellow Sea have also been lost over the past 30 years due to increased mariculture, opening up to salt-pans and agriculture.

Substantial changes have occurred in species composition and abundance of benthic organisms in the muddy foreshores, for example in the Changkou area. The benthos used to have about 170 species in the 1950s but this was reduced to some 70 species in the 1980s and to only a few in 1990s that were resistant to the changed environment. The introduction of *Spartina* had greatly altered the ecology of the system, further reducing the biodiversity.

An example of foreshore development is shown in Figure 15. This shows the extension of agriculture on the foreshore of Chongmin Dao on the south side of the Changjiang estuary between 1990 and 2004.

Figure 15. Example of Foreshore Development.



From the perspective of biodiversity, the main effect of habitat loss is on the composition of assemblages of organism communities in tidal mudflats, especially benthic organisms, waterbirds and reduced resting and feeding grounds for migratory birds. At least 40 sites have been identified as globally, or potentially globally, significant for waterbirds on the Yellow Sea coast. The west coast of the Republic of Korea has a rather higher density of globally significant sites for migratory waterbirds than the Chinese coast of the Yellow Sea.

The main cause of habitat loss has been land reclamation, especially in estuaries and shallow bays. Coastal mudflat reclamation has been mainly for expansion of aquaculture and mariculture, industrial development and tourism.

Approximately 880,000 ha of Yellow Sea mudflat areas have been reclaimed. This comprises 37% of the inter-tidal areas of the Chinese portion of the Yellow Sea, which have been reclaimed since 1950, and 43% of the mudflats on the ROK coast, which have been reclaimed since 1917 (Barter 2002). It has been claimed that China has plans to reclaim a further 45% of its existing mudflat in the Yellow Sea and the ROK plans to reclaim a further 34% of its coastal margin (Barter 2002). The aggregate consequence of these activities is that a majority of coastal wetland areas and tidal mudflats will have been reclaimed for land development purposes within the next decade. This will have a most severe effect on tidal flat communities of organisms, including waterfowl, in the region and will much reduce the areas suitable for resting and feeding of migratory birds.

Another example of habitat loss is the reduction in the number of lagoons on the border of the Yellow Sea. The number of lagoons in Shandong Province has been reduced from the original 29, 30 years ago, to only 3 or 4 today. During the last 30 years, more than 30% of the lagoons in the edge of the Yellow Sea have been lost. The production of sea cucumbers around Yuehu Lake in Shangdong Province used to be thousands of kilograms per year but has now been reduced to tens of kilograms per year. Such a large decrease in the production of sea cucumbers can be attributed to uncontrolled over-exploitation. Overgrowth and subsequent deterioration of the macro-seaweeds has further modified the remaining lagoons thereby reducing the goods and services that they provide.

The second environmental problem listed by the RWG-B is “Pollution”. Unfortunately, apart from one or two instances, the term “pollution” has been used generically and therefore only limited specification of the kinds of pollution affecting biodiversity has been

provided. It should be noted that the term "marine pollution" is internationally defined (GESAMP, 1969) as an "adverse effect" rather than the mere introduction of material into the marine environment. Thus, pollution itself constitutes an adverse consequence of the release of material into the sea. In the context of biodiversity, the pollution that degrades habitats is anything that contaminates or changes the nature of the habitat in a way that makes it less desirable to some organisms and, sometimes, more suitable for others. For example, Yellow Sea salt marshes are the habitats of a number of endangered species, such as the red-crown crane and reindeer. Measures to protect salt marshes have been taken by the Chinese Government and this has reduced the loss of salt marshes to less than 30% during the last 30 years. Salt marshes in the Chengshantou have been well maintained with swans having returned. However, a sign of some ecological change has been evident in recent years as a result of the indiscriminate discharge of sewage from the surrounding urban centres. The main pollutants referred to in the biodiversity synthesis as of concern from a biodiversity perspective are dissolved nitrogen, dissolved phosphorus, oil, chemical oxygen demand (COD) and sewage. References are also made to heavy metals, specifically Pb and Hg, and the threat they pose to offshore water. Only in the case of sewage discharge is there a specific reference to the consequences on diversity, namely drastic decreases in the production of penaeid shrimps (*Penaeus* spp.) and scallops (*Pecten* spp). Nevertheless, all of the forms of contamination and their effects outlined in the biodiversity synthesis are dealt with in the pollution sections of this document and are not addressed further here because the specific nature of damage and threats to biodiversity have not yet been expounded sufficiently.

The third environmental issue raised is "Changes in river discharge". This is clearly relevant to biodiversity as such changes will alter both the salinity and temperature (in summer and winter primarily) regimes in coastal areas influenced by major freshwater discharges. In large part, this issue would be most evident on the Chinese coast of the Yellow Sea where the earlier influence of freshwater discharge to the Bohai Sea from the Yellow River has been much reduced and in inshore areas influenced by smaller rivers whose flow has been modified by engineering works in their drainage basins. One correlated change will also be reductions in sediment discharge from these rivers as a result of the retention of suspended sediment and bedload upstream of impoundments. This can lead to sediment impoverishment in nearshore and deltaic areas that will inevitably result in habitat change. It has already

been noted that the deltaic sediments offshore of the old mouth of the Yellow River in the western Yellow Sea are being eroded through remobilisation.

The fourth issue is "Overexploitation of marine and coastal living resources". This issue is addressed in the fisheries sections of this document. The concomitant effects on biodiversity will be evident from these sections.

The fifth issue identified in respect to biodiversity is the "Introduction of xenobiotic (alien) species". An integrated investigation of exotic/introduced species has not yet been conducted but there are some examples. The issue has two facets: first, the deliberate introduction of species primarily for aquaculture and mariculture in the Yellow Sea basin; and, second, the inadvertent introduction of alien species through ballast water and vessel hull transport. Examples include: scallops introduced from Japan and USA that have become an important mariculture species; kelp and Suringar (*Undaria pinnatifida*) of Japanese origin that have been growing widely along the coast of Yellow Sea and have developed into endemic communities; and *Spartina anglica* from the UK and USA that has been dispersed along the coast, especially in Jiangsu Province.

It is evident then that the habitats bordering the Yellow Sea have been, and continue to be, changed by developmental activities. It is also evident that both habitat change and other deliberate and inadvertent activities have resulted in changes in the biodiversity of the Yellow Sea system. It is, however, not possible with currently available information, either to provide a comprehensive appraisal of the changes in biodiversity that have occurred or to quantify the social and economic costs associated with these changes.

Interestingly, in the context of biodiversity protection in the Yellow Sea, the World Wide Fund for Nature (WWF), in collaboration with the Korea Ocean Research and Development Institute (KORDI) and the Korea Environment Institute, has produced a map showing priority areas for biodiversity conservation in the Bohai Sea and the Yellow Sea from the perspectives of birds, fish, molluscs, plants and algae (WWF et al., 2006). This map is reproduced here as Figure 16 while Table 10 shows the names of each of the areas depicted. The original work (WWF et al., 2006) specifies which species and sub-areas have been included in each of the areas shown in Figure 16. This material can be used as a guide to the most important areas of the region deserving of protection from biodiversity perspectives.

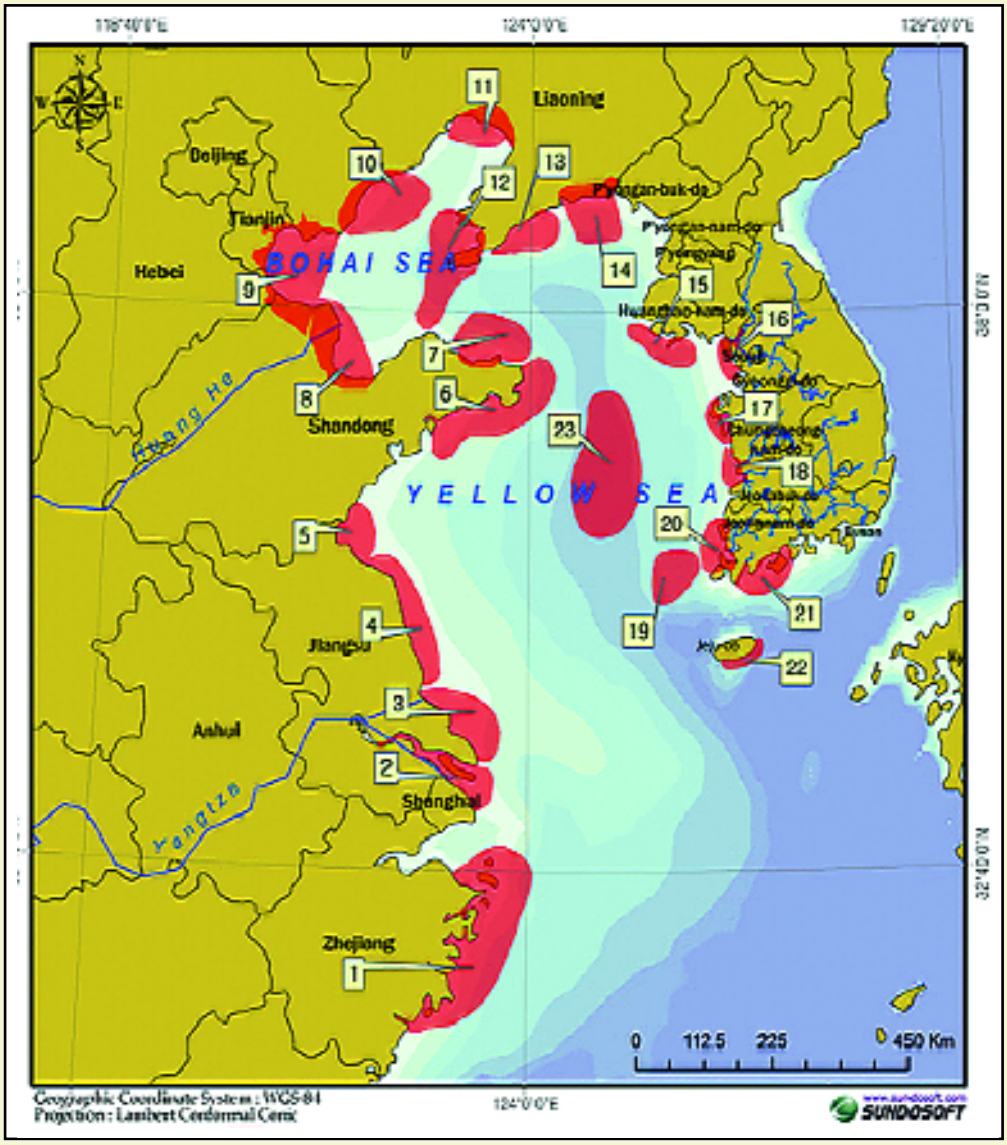
Table 10. Names of the Priority Areas for Biodiversity Protection in the Bohai and Yellow Seas Shown in Figure 16.

No.	Area Name	No.	Area Name	No.	Area Name	No.	Area Name
1	Zhoushan Archipelago	7	Yanwei	13	Changshandao s Island	19	Huksando Island
2	Yangtse Estuary Wetland	8	Huanghe-Leizhouwan	14	Yalujiang Estuary	20	Yeongsangang Estuary
3	S. Jiangsu Coast	9	Bohaiwan	15	Baengnyeongdo – Yeonpyeongdo Islands	21	Boseong-Yeoja Bays
4	N Jiangsu Coast	10	Qinghuangdao	16	Gyeonggi Bay	22	Jeju Island
5	Haizhou Bay	11	Liaohe Estuary	17	Cheonsu Bay	23	Yellow Sea Cold Water
6	Qing-Shi	12	Haiyangdao - Changxing Islands	18	Geumgang-Mangyeongang – Dongjungang Estuaries		

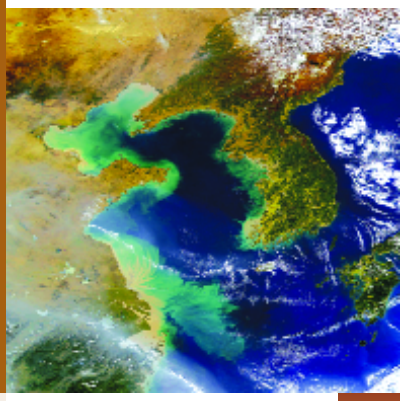
In conclusion, the foregoing discussion has established the nature of environmental problems in the region that warrant being addressed in the regional Strategic Action Programme (SAP). These all need to be subjected to causal chain analysis to identify their immediate, proximal, distal and root causes. The options for management intervention are identified through the results of causal chain analysis.

Figure 16. Priority Areas for Biodiversity Conservation in the Yellow Sea.

(After WWF et al., 2006)



6. CAUSAL CHAIN ANALYSIS



This section contains the causal chain analyses for the environmental problems identified in each of the technical components of the project in the preceding Section 5. Each category of problem is presented in the sequence: pollution, ecosystem, fisheries and biodiversity. Colour coding has been used in the causal chains to show primary chains and to provide information regarding the relative severity and trends of individual problems in each of the project components. This colour coding is shown in Table 11 below.

In completing the causal chains for the problems identified in each of the main project components an attempt has been made to include three levels of intermediate cause (2nd, 3rd and 4th level causes) between the immediate and root cause. Such a level of detail is not, however, possible in the case of all identified problems. Therefore, gaps among intermediate causes indicate instances in which the inclusion of an entire set of intermediate causes was not possible. In such cases, the root cause is entered as the fundamental cause of the problem concerned. There are also several instances in which one RWG identified as the cause of a problem an issue that had been identified by another RWG. In such cases, the causal chain makes a direct reference to the category and problem for which the causal chain presented there is relevant.

Table 11. Colour Coding Used in Causal Chain Analyses

Column	Colour Code	Meaning
Priority		Severe problem
Priority		Serious problem
Priority		Comparatively minor problem
Trend		Problem becoming more severe
Trend		No trend or trend indiscernible
Trend		Trend is towards improvement
Causes		Primary causal chain
Root Cause(s)		Advisory note

6.1. Pollution Problems

The causal chain analyses for problems identified in the pollution component of the project are presented in Table 12. These are categorized in a form consistent with the list of problems in Table 3.

6.2. Ecosystem Problems

The causal chain analyses for problems identified in the ecosystem component of the project are presented in Table 13. These are categorized in a form consistent with the list of problems in Table 4.

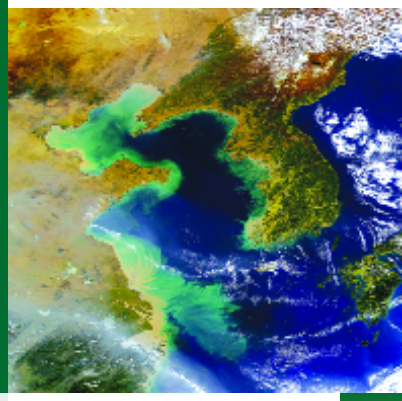
6.3. Fisheries Problems

The causal chain analyses for problems identified in the fisheries component of the project are presented in Table 14. These are categorized in a form consistent with the list of problems in Table 5.

6.4. Biodiversity Problems

The causal chain analyses for problems identified in the biodiversity component of the project are presented in Table 15. These are categorized in a form consistent with the list of problems in Table 9

7. ANALYSIS OF ROOT CAUSES



The causal chain analysis provides a basis for identifying options for management intervention. Such options for intervention, to reduce or rectify a given problem, exist in relation to each cause of the problem from immediate cause through secondary, tertiary and quaternary causes to the root cause as shown in Figure 1. As there noted, interventions primarily directed at rectifying the root causes of problems are generally to be preferred because they often address the causes of several problems and are usually more cost effective.

However, it generally takes longer to develop a systematic and commonly-agreed form of intervention to address a root cause because it can only be developed within a policy framework. This is one of the primary reasons why the development of a Strategic Action Programme is a process that must engage all stakeholders including politicians.

The development of fundamental solutions to problems frequently involves reconsideration of existing policies and legislation and requires a thorough analysis of the benefits and drawbacks of adopting particular forms of action to address environmental compromise.

This section is devoted to identifying the causes of environmental problems that provide the basis for identifying options for intervention. In the next section of the TDA these options are analysed to determine those most worthy of consideration in the development of the SAP.

Table 12. Causal Chain Analysis – Pollution Problems

Issue/ Concern	Fundamental Problem/Driver	Priority	Trend	Primary Cause(s)	Secondary Cause(s)	Tertiary Cause(s)	Quaternary Cause(s)	Root Cause(s)
Eutrophication and Harmful Algal Blooms	Nitrogen Enrichment			Sewage discharge (treated and untreated) into the sea and rivers.	No tertiary sewage treatment	Little attention given to the capacity of the Yellow Sea to absorb Nitrogen	no quantitative knowledge on capacity of system to absorb Nitrogen	Limited application of research knowledge to assimilative capacity calculations
					Inadequate urban sewage treatment capacity	Korea – limited investment in urban infrastructure China – rapidly increasing urban populati		Limited influence of environmental consultancy on government policies
					Inadequate storm water drainage / separation of sewage and stormwater drainage systems	Cost of separating storm and sewage water in long established urban areas.		
						Where such separation exists, it is frequently over whelmed by major storm events.		
				Wastewater discharges from chemical industries	Limited assurance of compliance with existing standards and regulations	Inadequate govt compliance assurance system.	Inadequate compliance with regulations.	Limited compliance assurance infrastructure.
					Inadequate attention to the capacity of receiving waters to absorb Nitrogen	Limited incentives for industry to abide by government regulations.	Limited stakeholder involvement in industrial activities.	Limited compliance assurance infrastructure.
				Residues released from mariculture	Density of mariculture exceeds capacity to absorb Nitrogen (compounded by over feeding of stock)	Lack of recognition of the assimilative capacity of the YS system to absorb nutrient releases.	Weak government regulatory system.	Limited influence of environmental consultancy on government
						Market demand exceeds environmental consideration	Weak government regulatory system.	Limited influence of environmental consultancy on government.
				Agriculture – arable farming runoff	Overuse of fertilizers on crops	Lack of labour for proper fertilizer application.	Migration of rural population to urban centres.	Employment opportunities in industrial/service centres.
						Lack of knowledge of proper application Korea – market incentives for increased production of non rice crops with limited farmer understanding	Insufficient government requirements for farmer training Korea – attempts to reduce imports of food stuffs	National pressures for self sufficiency in foodstuffs
							China – attempts to improve balance between supply and demand for agricultural products	
					Limited control of waste runoff from agricultural activities.	No use of buffer zones for nutrient assimilation	Inadequate recognition of problem at national levels	Inadequate balance between development and environmental protection policy

Table 12. Causal Chain Analysis – Pollution Problems (Continued)

Eutrophication and Harmful Algal Blooms (Continued)	Nitrogen Enrichment (Continued)		Agriculture – animal husbandry runoff	Leakage of animal wastes into fresh waters.	No use of buffer zones for nutrient assimilation.	Inadequate recognition of problem at national levels.	Inadequate balance between development and environmental protection policy
			NO_x emissions from vehicles	Major increase in number of vehicles	Substantial increase in standard of living	Massive economic development	Limited adoption of regulations on vehicular sources
Toxic Algal Blooms	Silicate depletion (relative to N and P)		Retention of fixed Silicate behind freshwater dams	Construction of dams on major rivers draining into the Bohai and Yellow Seas	Freshwater storage and power production to support economic development	Economic development without adequate consideration of marine environmental consequences	Limited development and improvement of coherent policies on the maintenance of nutrient balances
Contaminants and Their Effects (i.e., Pollution)	Fecal bacterial contamination and associated risks to human health		Discharge of human sewage	Inadequate urban sewage treatment capacity	Korea – limited investment in urban infrastructure China – rapidly increasing urban populations	Limited incidence of disease caused by contact with contaminated seawater and seafood consumption	Limited attention to the problem of sewage treatment in relation to human health protection
	PAH contamination		Shipping emissions	Increase in number and size of vessels			Limited compliance with MARPOL Convention
			Power generation emissions	Limited use of desulphuric scrubbers	Growth in demand for electrical power	Inadequate recognition of problem at national levels	Limited development of emission controls on industry
			Oil spills	Increased maritime traffic			
			Oil refinery emissions	Increased PAH releases from refining activities	Increased demand for refined oil products	Limited controls on PAH releases	Limited development of controls on emissions from industry
			Steel production emissions		Increased demand for steel	Limited controls on PAH releases	Limited development of controls on emissions from industry
			Home heating emissions	Limited use of renewable energy sources for home heating purposes	Limited incentives for renewable power generation		Absence of behavioral energy policy based on the need to mitigate climate change and protect the environment
			Diesel engine emissions				
			Road paving emissions				

Table 12. Causal Chain Analysis – Pollution Problems (Continued)

Contaminants and Their Effects (i.e., Pollution) (Continued)	Heavy metal contamination (Hg, Pb, Zn, Cu, Hg, Cr)			Release of metals from industry	Inadequate compliance with existing regulations	Limited compliance assurance infrastructure		Inadequate compliance assurance
				Agriculture – animal husbandry runoff	Limited consideration of receiving capacity of the receiving environment	No quantitative knowledge of capacity of system to assimilate metals	Limited application of research knowledge to calculation of assimilative capacity	
				Releases of metals from vehicles	Limited restrictions in metals releases from transport	No justification for increased controls associated with blood Pb levels		
	PCB contamination			Long distance transport from other areas	Emissions to atmosphere in other regions of the world	No jurisdictional influence except through international conventions		NB: Development and administration of regulations will be promulgated under NIPs for implementation of the Stockholm Convention
				Release of used PCB-containing dielectric/coolant oils	Inadequate facilities for decommissioning transformers, capacitors and other PCB-containing equipment in the electrical industry			NB: Development and administration of regulations will be promulgated under NIPs for implementation of the Stockholm Convention
	PCDD & PCDF Contamination			Incineration of solid wastes	Inadequate segregation of wastes	Inadequate waste management practices	Poor regulation of solid waste management and recycling	NB: Development and administration of regulations will be promulgated under NIPs for implementation of the Stockholm Convention
				Steel industry	Uncontrolled combustion without scrubbing	Limited implementation of release controls		NB: Development and administration of regulations will be promulgated under NIPs for implementation of the Stockholm Convention
				Pulp and paper industry	Use of old pulping technologies and contaminated feedstock	Limited implementation of process and release controls		NB: Development and administration of regulations will be promulgated under NIPs for implementation of the Stockholm Convention
	Marine litter contamination			Releases of anthropogenic wastes from land-based sources	Inadequate solid waste management	Lack of appreciation that marine litter is a problem		Poor public education
					Public / tourist habits	Lack of appreciation that marine litter is a problem		Poor public education
				Transport of natural materials from land-based sources into the marine environment	Carriage of natural materials entrained by floods and storms	Inadequacies in land management – forestry, agriculture, parks and public spaces		Inadequacies in public policies, legislation and regulations to address comprehensively land-based sources of marine pollution

Table 13. Causal Chain Analysis – Ecosystem Problems

Issue/ Concern	Fundamental Problem/Driver	Priority	Trend	Primary Cause(s)	Secondary Cause(s)	Tertiary Cause(s)	Quaternary Cause(s)	Root Cause(s)
Change in biomass or abundance	Increase in Noctiluca (>200µm zooplankton)			Change of phytoplankton abundance and composition	Change in physical conditions	Regional climatic changes	Global climate change	N.B. This is a global issue and relates to the implementation of FCCC. Both countries are parties to the Kyoto Protocol
				Decrease predator pressure and change in food items consumed	Change in fish community	Overfishing	Increasing demand for seafood	Weak enforcement of controls on fishing as a means of preventing illegal fishing activities
	Decrease in China (greater than 330µm zooplankton; greater than 77µm phytoplankton)			Change of nutrient concentrations and ratios	Change in sewage discharge, reduced freshwater loading, and increased use of fertilizers	Rapid development in coastal zone and the interior without adequate environmental protection	Inappropriate balance between economic development and environmental protection	Limited coverage of legislation and/or inadequate enforcement of legislation relating to coastal zone management and protection
	Shift in peak in seasonal patterns of zooplankton biomass (Korea)			Change of phytoplankton abundance and composition	Change in physical conditions	Regional climatic change	Global climate change	N.B. This is a global issue and relates to the implementation of FCCC. Both countries are parties to the Kyoto Protocol
				Decrease predator pressure and change in food item consumed	Change in fish community	Overfishing	Increasing demand for seafood	Weak enforcement regarding illegal fishing activities
Change in species composition	Change in dominant groups of zooplankton (Korea)			Change of phytoplankton abundance and composition	Change in physical conditions	Regional climatic change	Global climate change	N.B. This is a global issue and relates to the implementation of FCCC. Both countries are parties to the Kyoto Protocol
	Changed ratio of diatoms to dinoflagellates (China)			Change of predator (top down control)	Overfishing	Rapid increase in fishing effort	Insufficient controls on fishing activities inconsistent with requirements of UNCLOS	Weak enforcement of controls on fishing as a means of preventing illegal fishing activities
				Change in nutrient concentrations and ratios	Changed nutrient influxes	Increased sewage discharge, reduced fresh water loading	Rapid development of coastal zone	Weaknesses in legislation and/or inadequate enforcement of legislation relating to coastal zone management and protection
	Jellyfish blooms			Change in physical environment, such as temperature, salinity, and mixing	Climatic change	Increased atmospheric concentration of CO_2	Rapid global economic development	N.B. This is a global issue and relates to the implementation of FCCC. Both countries are parties to the Kyoto Protocol

Table 13. Causal Chain Analysis – Ecosystem Problems

Issue/ Concern	Fundamental Problem/Driver	Priority	Trend	Primary Cause(s)	Secondary Cause(s)	Tertiary Cause(s)	Quaternary Cause(s)	Root Cause(s)
Change in species composition (Continued)	Change in benthic species composition and dominant species			Degradation of bottom water environment and sediment quality; changes in surficial sediment composition	Stagnation of bottom water due to thermal stratification	Changes in Yellow Sea circulation	Climate change	N.B. This is a global issue and relates to the implementation of FCCC. Both countries are parties to the Kyoto Protocol
				Change in predation pressure	Change in species composition and fish community (more pelagic than demersal fish species)	Overfishing of demersal fish		See Fisheries causal chain
Increased frequency of HABs	Eutrophication** (See Pollution causal chain)							See Pollution causal chain
	Si depletion** (See Pollution causal chain)							See Pollution causal chain
Loss of benthic habitat in coastal areas	(See Biodiversity causal chain)							See Biodiversity causal chains

Table 14. Causal Chain Analysis – Fisheries Problems

Issue/ Concern	Fundamental Problem/Driver	Priority	Trend	Primary Cause(s)	Secondary Cause(s)	Tertiary Cause(s)	Quaternary Cause(s)	Root Cause(s)
Decline in landings of many traditional commercially important species and increased landings of low value species (including changes in dominant species)	Unsustainable natural resource exploitation practices			Overexploitation of target fish species	Over capacity of fishing fleets	Lack of alternative livelihood. Unchecked increase in demand for capture fish as the result of changing lifestyle	Deficiencies in management and control of fisheries activities	Lack of comprehensive and effective system of fisheries stock management
							Insufficient monitoring and enforcement	Lack of compliance assurance procedures
					Deficiencies in fisheries research management	Weak scientific-based knowledge of ecosystem processes	Insufficient support for, and guidance of, education and research	Poor recognition of the limits to sustainable natural resource exploitation
				Climatic change				See Ecosystem causal chain
Unsustainable mariculture practices	Unsustainable development of coastal zone			Over intensive mariculture	Unguided/unchecked increased in demand for seafood as the result of changing lifestyle	Lack of scientific and technical guidelines for mariculture practices	Inadequate controls and regulations for mariculture development	Coastal development undertaken with limited comprehensive and coherent legislation that provides adequate environmental protection
				Limited and variable natural food supply	Variation of environmental conditions (e.g., primary productivity) combined with extensive mariculture activities	Insufficient knowledge of carrying capacity	Limited application of science to regulation of mariculture activities	Deficiencies in the application of science to environmental protection and coastal zone development
				Over-exploitation of natural habitats	Inappropriate management plan based on zoning of mariculture areas	Insufficient strategies for preserving and improving coastal zone development plans based on the maintenance of ecosystem services	Inadequacies in the control and regulation of developmental activities in coastal areas	Lack of comprehensive and coherent framework for coastal and marine resource development
				Environmental consequences of release of nutrients, bacterial, viral and faecal matter and food residues from mariculture	Overfeeding, inadequate effluent treatment, poor quality of feed	Insufficient application of environmental friendly techniques and considerations of carrying capacity	Inadequacies in the control and regulation of developmental activities in coastal areas	Lack of comprehensive and coherent framework for coastal and marine resource development
				potential impacts on human health	Chemical and pharmaceutical residues in farmed organisms	Inappropriate use of chemicals in mariculture and frequent algal blooms	Insufficient application of environmental friendly techniques and environmental changes	Lack of coordination between public health sector, government agencies and the private sector
					Effects of natural toxins generated by harmful algal blooms (HABs)	Eutrophication		See Pollution causal chain

Table 14. Causal Chain Analysis – Fisheries Problems

Issue/ Concern	Fundamental Problem/Driver	Priority	Trend	Primary Cause(s)	Secondary Cause(s)	Tertiary Cause(s)	Quaternary Cause(s)	Root Cause(s)
Habitat loss and degradation	Benthic habitat loss			covering of benthic habitat with wastes	inappropriate solid waste disposal practices	poor compliance with regulations	Lack of public awareness	Development being undertaken with limited comprehensiveness and coherence in the legislative basis for environmental and biodiversity protection coupled with poor enforcement and inadequate public information
	Coastal dependent habitat loss			land reclamation	Rapid industrial and social development in the coastal zone	Development undertaken without full understanding of the consequences	Deficiencies in comprehensive development planning	
	Pollution			Domestic and industrial waste discharges	Growth of urban conurbations and associated industry in the coastal zone	Development undertaken without full understanding of the consequences	Deficiencies in comprehensive development planning	
	Loss of habitat in estuaries/deltas			Reductions in river discharge Sediment impoundment	River basin development (construction of dams for water impoundment and power generation)	Pressure for hinterland development, power production, irrigation and improved water supplies	Development undertaken without full understanding of the consequences	
				Changes in locations and amounts of river discharge	River diversion schemes			
	Habitat conversion			Reclamation for aquaculture ponds for shrimp and milkfish	Increasing demand for seafood	Lifestyle changes and increased disposable plentiful and affordable supply of seafood	Population growth and increased affluence	
					Demand for job opportunities	Social development with increased personal aspirations		
				Reclamation for salt production	Increasing demand for edible salt	Rapidly growing population		
					Increasing demand for chemical products	Requirement for more chemical products for rapidly growing population		
	Habitat degradation			Degradation and fragmentation of habitat due to natural change and human activities	Indiscriminate land and community development	Land development undertaken without full understanding of the consequences	Deficiencies in comprehensive development planning	
					Climatic change			See Pollution Causal Chain

Table 15. Causal Chain Analysis – Biodiversity Problems (Continued)

Issue/ Concern	Fundamental Problem/Driver	Priority	Trend	Primary Cause(s)	Secondary Cause(s)	Tertiary Cause(s)	Quaternary Cause(s)	Root Cause(s)
changes in species abundance and diversity	Decline in vulnerable birds			Overhunting	Sustainability not considered by local harvesters	Highdemand for food including the continuation of traditional exploitation practices	Continuation of traditional practices without regard for consequences of increased production	Deficiencies in policy and regulation of traditional natural resource exploitation practices and inadequate public information
				Unsustainable egg harvest				
				Destruction of reproductive, resting and feeding habitat especially coastal wetlands	Lack of consideration of aquatic protection in social and economic development practices	Inadequate balance between development aspirations and the need to protect the environment and biodiversity	Deficiencies in comprehensive development planning	Development being undertaken in the absence of comprehensive and coherent legislation for environmental and biodiversity protection combined with poor enforcement of existing legislation
	Decline in Sea Turtles			Climatic change	Sustainability not considered by local harvesters	Highdemand for food including the continuation of traditional exploitation practices	Continuation of traditional practices without regard for consequences of increased production	See Pollution Causal Chain Deficiencies in policy and regulation of traditional natural resource exploitation practices and inadequate public information
				Unsustainable egg harvest				
				Destruction of reproductive habitat	Lack of consideration of aquatic protection in social and economic development practices	Inadequate balance between development aspirations and the need to protect the environment and biodiversity	Deficiencies in comprehensive development planning	Development being undertaken in the absence of comprehensive and coherent legislation for environmental and biodiversity protection combined with poor enforcement of existing legislation
				Overexploitation	Sustainability not considered by local harvesters	Inadequate controls on natural resource exploitation practices	Continuation of traditional practices without regard for consequences of increased production	Deficiencies in policy and regulation of traditional natural resource exploitation practices and inadequate public information
	Decline in anadromous and catadromous[14] fish and mammals							

[14] Anadromous and catadromous species are those whose life cycle includes periods spent at sea and periods spent in freshwater.

Table 15. Causal Chain Analysis – Biodiversity Problems (Continued)

Issue/ Concern	Fundamental Problem/Driver	Priority	Trend	Primary Cause(s)	Secondary Cause(s)	Tertiary Cause(s)	Quaternary Cause(s)	Root Cause(s)
Changes in species abundance and diversity (Continued)	Decline in anadromous and catadromous fish and mammals (Continued)			Spawning/migration route blocked by dams	Construction of river barriers without adequate consideration of environmental and biodiversity consequences	Inadequate balance between development aspirations and the need to protect the environment and biodiversity	Deficiencies in comprehensive development planning	Development being undertaken in the absence of comprehensive and coherent legislation for environmental and biodiversity protection combined with poor enforcement of existing legislation
				Accidental injury	Increased maritime transport			
				By-catch	Inappropriate fishing practices	inadequate controls on fishing practices	deficiencies in fisheries management	weak enforcement of controls on fishing activities
	Decline in vulnerable species e.g., Hemichordata, Polychaeta, Brachiopoda, molluscs and shrimp			Physical destruction by bottom trawling	Inappropriate fishing practices	Inadequate controls on fishing practices	Deficiencies in fisheries management	Development being undertaken in the absence of comprehensive and coherent legislation for environmental and biodiversity protection combined with poor enforcement of existing legislation and inadequate public information
				Overexploitation of species	Demand for seafood	Increased population and increased affluence	Deficiencies in fisheries management	
				Destruction of spawning, nursery and overwintering grounds	Inadequate recognition of the importance of habitat protection to the maintenance of environmental quality and sustainable use & biodiversity protection	social and economic development considerations outweighing environmental and biodiversity protection concerns		
					Climatic change			See Pollution Causal Chain
	Loss of species and diversity			Loss of habitat	(see habitat removal degradation)			
	Decline of endemic pelagic and demersal fish species			Overexploitation of marine and coastal living resources	Overfishing			See Fisheries Causal Chain
	Introduction of xenobiotic (alien) species			Hull and ballast water transport of non-indigenous organisms	Marine transport	Inadequate control and regulation of ballast water collection and discharge		Ad-hoc, limited implementation of the provisions of the Ballast Water Convention

7.1. Causes of Pollution Problems

There are few commonalities among the immediate causes of pollution problems (table 12). These causes are associated with releases from specific industries, transport sources, agricultural activities, mariculture and municipal sources, especially sewage and solid wastes. They also include the construction of engineering works, such as dams, on watercourses, particularly major rivers. Among these causes, the most frequent are releases from industrial, agricultural and municipal sources that contribute to eutrophication, faecal contamination and marine litter. Much the same situation applies at the level of secondary causes where the issues associated with inadequate controls on agricultural and municipal waste management practice are again highlighted. Among tertiary causes there exists greater emphasis on the lack of controls in a variety of human and industrial activities, limited investment in the infrastructure for waste management and control infrastructure and rapid economic and social development, especially in China. Among quaternary causes there occurs increased emphasis on the lack, or poor implementation, of controls in the field of waste management and an inadequate balance in policies relating to economic expansion and environmental protection. This latter cause becomes dominant in the list of root causes although there are instances in which it is noted that improvements can be expected in respect to some problems (particularly those relating to maritime transport and the implementation of the Stockholm Convention). Under root causes there are also references to the limited influence of the environmental constituency on government and inadequacies in contemporary policy priorities that fail to take sufficient account of environmental threats and compromise.

7.2. Causes of Ecosystem Problems

In the case of the causal chain for ecosystemic problems, the **first and second levels of cause** lie predominantly in the scientific domain where the causes of a particular change in condition generating concern has an immediate and secondary cause in the realm of the natural sciences. This is a peculiarity of the way in which the RWG-E has identified and analysed problems in the ecosystem (table 13) . It is only at the **tertiary cause** level that anthropogenic activities become identifiable and these include overfishing and climatic change putatively associated with an increased concentration of carbon dioxide in the atmosphere.

Among **quaternary causes** are global climatic change and rapid coastal zone development combined with an inappropriate legislative or regulatory balance between economic development and environmental protection. As might be expected, the root causes most commonly cited are limited progress in mitigating the releases of carbon dioxide to the atmosphere and, specifically, the limited expectations and achievements of the 1997 Kyoto Protocol. Other **root causes** include weak enforcement of controls on fishing activities and legislative and administrative weaknesses in facilitating adequate protection of the coastal zone in the context of the pace of economic development in the region.

7.3. Causes of Fisheries Problems

The causal chains for the two fisheries problems identified by the RWG-F are analogous in the sense that they both include subordinate socio-economic and scientific causal chains (table 14).

In the case of the decline in the landings of commercially important species, the **immediate causes** are identified as overexploitation of target fish species and climatic change respectively. The overexploitation of target fish species is attributed to both overcapacity in the fishing sector (e.g., too many fishing vessels chasing a reduced stock of target fish) and deficiencies in fish stock management. These latter two **secondary causes** then follow separate causal chains into tertiary causes, one socio-economic and the other scientific.

The first **tertiary cause** relates to the lack of alternative livelihoods and the unchecked demand for seafood. The **quaternary causes** in this chain are deficiencies in the management and control (regulation) of fisheries with the root causes being the lack of a comprehensive and effective system of fish stock management and the lack of compliance assurance infrastructure. The other (scientific) causal chain assigns a **tertiary cause** as a weakness in the scientific knowledge of ecosystem processes that places limits on the degree to which comprehensive stock management can be developed. The **quaternary causes** are essentially weaknesses in support for education and research. The **root cause** in this chain becomes poor recognition (in the policy sector and among government agencies) of the limits to sustainable natural resource exploitation.

In relation to unsustainable maricultural practices, the **primary causes** are

similarly split into socio-economic and scientific causal chains. The socio-economic primary causes include over-intensive maricultural development, the over-exploitation of natural habitats, the consequences of the releases of material (nutrients, bacteria, viral and faecal matter, and food residues) having adverse effects on the environment and human health concerns. In reviewing the causal chain in Table 14, it might appear that the environmental and human health consequences of excessive maricultural development are ***effects*** rather than ***causes***. However, it must be remembered that the stated problem is ***unsustainable*** mariculture and, accordingly, these actual or potential effects become the reason, or causes, of the unsustainability. The scientific causes, primarily the variability of environmental conditions, again follow into ***secondary and tertiary causes*** of limited scientific knowledge and limited application of science to the regulation of maricultural development.

The **root causes** in all causal chains for unsustainable mariculture appear as a lack of comprehensive and coherent legislative framework for coastal zone and maritime resource development, a lack of coordination among sectors, and deficiencies in the application of sound science to sustainable coastal development.

7.4. Causes of Biodiversity Problems

The biodiversity causal chains differ slightly from those for the other project components (table 15). Several of the **immediate causes** of problems are identical or similar to the problems in other components such as overexploitation of fisheries and loss of habitat. Climatic change also appears as a contributory cause of the decline of vulnerable species that are also important components of Yellow Sea biodiversity. In this latter case, and also where climatic change appears as a **secondary cause**, reference is made to the causal chains for the pollution component of the project. Other secondary causes include rapid economic development, increased demand for seafood, engineering works on watercourses and inappropriate fishing practices. It is, however, at the level of **tertiary causes** that a reduced number of causes become evident. The entry "inadequate balance between developmental aspirations and the need for protection of the environment and biodiversity" occurs frequently as does "inadequate controls on fishing and natural resource exploitation practices", which includes reference to "traditional exploitation practices". Other entries include "poor compliance with

regulations" and "pressure for hinterland development, power production, irrigation and water supplies". These are further narrowed at the level of **quaternary causes** primarily into deficiencies in comprehensive development planning and deficiencies in fisheries management. The biodiversity causal chain results in several forms of the **root causes** but all contain a similar message, namely that development is proceeding in the absence of comprehensive and coherent legislation to ensure concomitant environmental and biodiversity protection and that there also exists poor enforcement of existing legislation and inadequate provision of public information.

7.5. Commonalities Among Root Causes

Table 17 lists the most common root causes in all technical components of the project, the components and problems with which they are associated and their frequency of occurrence. This provides a guide to the most common causes for which intervention might be warranted. Furthermore, despite small differences in wording that result from the independent development of each of the causal chains in each of the project components, there is even greater commonality among root causes than this table immediately suggests.

The most frequent root cause "Development being undertaken with limited comprehensiveness and coherence of the legislative base for environmental and biodiversity protection coupled with poor enforcement and inadequate public information" only differs from the second most frequent entry by the inclusion of the additional words "... and inadequate public information". Thus, the most frequent root cause appears no less than eighteen times as a root cause for the environmental problems in the Yellow Sea. Furthermore, the root cause "Inadequate balance between development and environmental protection policy" has much similarity to this major root cause, making the total entries for this class of root cause no less than twenty-one.

Table 17. Frequency of Root Causes

Root Cause	Associated Problems	Category*	Score
Development being undertaken with limited comprehensiveness and coherence to the legislative basis for environmental and biodiversity protection coupled with poor enforcement and inadequate public information	Habitat loss and degradation/benthic habitat loss/other Habitat loss and degradation/coastal shoreland habitat loss/land reclamation Habitat loss and degradation /pollution/domestic and industrial waste discharges Habitat loss and degradation /loss of estuarine/delta habitats/changes in river and sediment discharge from rivers Habitat loss and degradation /loss of estuarine/delta habitats/changes in locations and amounts of river discharge Habitat loss and degradation /habitat conversion/reclamation for aquaculture Habitat loss and degradation /habitat conversion/reclamation for salt production Habitat loss and degradation/habitat degradation Changes in species abundance and diversity/decline in vulnerable species/bottom trawling Changes in species abundance and diversity/decline in vulnerable species/overexploitation Changes in species abundance and diversity/decline in vulnerable species/destruction of spawning, nursery and overwintering grounds Unsustainable mariculture practices/ unsustainable development of coastal zone/over-intensive mariculture Unsustainable mariculture practices/ unsustainable development of coastal zone/over-exploitation of natural habitats Unsustainable mariculture practices/ unsustainable development of coastal zone/ environmental consequences of releases of nutrients,bacterial, viral and faecal matter and food residues from mariculture	B B B B B B B B B B P P P	1a
Development being undertaken with limited comprehensiveness and coherence of legislative basis for environmental and biodiversity protection combined with poor enforcement	Changes in species abundance and diversity/decline in anadromous and catadromous fish and mammals Changes in species abundance and diversity/decline in vulnerable bird species Changes in species abundance and diversity/decline in sea turtles Changes in species abundance and diversity/decline in anadromous and catadromous fish and mammals	B B B B	4
Weak enforcement of controls on fishing activities including illegal activities	Change in biomass or abundance/increase of > 200 µm zooplankton in Korea Change in biomass or abundance/shift in seasonal patterns of zooplankton biomass Change in biomass or abundance/changed ratio of diatoms to dinoflagellates Changes in species abundance and diversity/decline in anadromous and catadromous fish and mammals	B B B B	4
Limited compliance assurance infrastructure/ inadequate compliance assurance	Eutrophication/nitrogen enrichment/wastewater discharge from chemical industries Harmful algal blooms/eutrophication Contaminants/heavy metals/ releases from industry Decline in landings/unsustainable practices/ overexploitation of target fish species	P B P P	4
Limited application of research knowledge to assessment capacity and coastal zone development	Eutrophication/nitrogen enrichment/sewage discharge Contaminants/heavy metals/agricultural runoff Harmful algal blooms/eutrophication Unsustainable mariculture practices/ unsustainable development of coastal zone/ limited and variable natural food supply	P P B P	4

Table 17. Frequency of Root Causes

Root Cause	Associated Problems	Category*	Score
Deficiencies in policy and regulation of traditional natural resource exploitation practices and inadequate public information	Changes in species abundance and diversity/ decline in vulnerable bird species Changes in species abundance and diversity/ decline in sea turtles Changes in species abundance and diversity/ decline in anadromous and catadromous fish and mammals Decline in landings/ unsustainable practices/ overexploitation of target fish species	B B B P	4
Inadequate balance between development and environmental protection policy	Eutrophication/ nutrient enrichment/ agriculture-arable farming runoff Eutrophication/ nutrient enrichment/ agriculture-animal husbandry runoff Harmful algal blooms/ eutrophication	P P B	3
Limited development of controls on emissions from industry	Contaminants/ PAH contamination/ power generation emissions Contaminants/ PAH contamination/ oil refinery emissions Contaminants/ PAH contamination/ steel production emissions	P P P	3
Limited influence of environmental constituency on government policy	Eutrophication/ nutrient enrichment/ sewage discharge Eutrophication/ nutrient enrichment/ residues from mariculture Harmful algal blooms/ eutrophication	P P B	3
Weaknesses in legislation and/or inadequate enforcement of legislation relating to coastal zone management and protection	Change in biomass or abundance/ decrease of > 77µm zooplankton in China Change in species composition/ changed ratio of diatoms to dinoflagellates	B B	2
Inadequacies in public policies, legislation and regulations to address complex issues of land-based sources of pollution	Contaminants/ marine litter/ land-based sources	P	1
Absence of balanced energy policy based on the need to mitigate climate change and protect the environment	Contaminants/ PAH contamination/ boiler burning emissions	P	1
National pressures for self sufficiency in foodstuffs	Eutrophication/ nutrient enrichment/ agriculture-arable farming runoff	P	1
Limited development and implementation of coherent policies on summers	Toxic algal blooms/ shellfish poisoning/ presence of shellfish related toxins	P	1
Limited awareness to the problem of sewage treatment in relation to human health protection	Contaminants/ Faecal bacterial contamination/ discharge of human sewage	P	1
Limited adoption of regulations on vehicular sources of emissions	Eutrophication/ nutrient enrichment/ NOX emissions from vehicles	P	1
Limited compliance with the MARPOL Convention	Contaminants/ PAH contamination/ shipping emissions	P	1
Limited implementation of the provisions of the Ballast Water Convention	Change in species abundance and diversity/ decline in vulnerable species	B	1
Employment opportunities concentrated in rural centres	Eutrophication/ nutrient enrichment/ agriculture-arable farming runoff	P	1
Poor public education	Contaminants/ litter/ releases from land-based sources	P	1
Lack of comprehensive and effective system of fisheries stock management	Decline in landings/ unsustainable practices/ overexploitation of target fish species	P	1
Lack of coordination between public health sector, government agencies and the private sector	Unsustainable environmental practices/ unsustainable development of coastal zone/ potential impacts on human health	P	1

* Key
P = Pollution E = Ecosystem
F = Fisheries B = Biodiversity

Another root cause falling into the same category is "*Weaknesses in legislation and/or inadequate enforcement of legislation relating to coastal zone management and protection*" that results from problems associated with land-based activities. Such activities are covered by the UNEP Global Programme of Action on the Protection of the Marine Environment from Land-based Activities (UNEP 1995). In fact, the instances in which this latter root cause arises could have been equally well expressed as "Limited compliance with the UNEP Global Programme of Action on the Protection of the Marine Environment from Land-based Activities". Finally, the root cause "Limited influence of environmental constituency on government policy" that appears three times is also a contributor to this category of root causes. This provides a partial explanation for the lack of government action towards the development of a more coherent and comprehensive system of legislation that would provide a better balance between economic development and environmental protection. This, in turn, parallels another of the root causes – that relating to an inadequate balance between development and environmental protection policy.

Among other root causes, the most frequent is "Weak enforcement of controls on fishing activities including illegal activities" that appears four times. This is similar to the entry "Deficiencies in policy and regulation of traditional natural resource exploitation practices and inadequate public information" that appears in a further four instances. This emphasises the problems associated with poor management and regulation of fishing activities including traditional (i.e., artisanal) fishing practices.

Among the other frequent root causes is "Limited application of research knowledge to assimilative capacity and coastal zone development" This reflects the scientific opinion that it should be possible to estimate conservatively the capacity of the marine environment to assimilate waste materials based on contemporary knowledge of the physical, chemical and biological conditions. Such assimilative capacities should be calculable for semi-enclosed coastal areas of the Yellow Sea and the Yellow Sea as a whole. The approach could also be used to define the density of acceptable coastal development. Addressing this root cause would require the application of scientific knowledge to ensure that the use of the Yellow Sea as a receptacle for wastes and as a coastal area for development is carried out in a manner that minimises the adverse consequences. This has clearly not been done.

Also appearing as an intermediate frequency root cause is "Limited compliance assurance

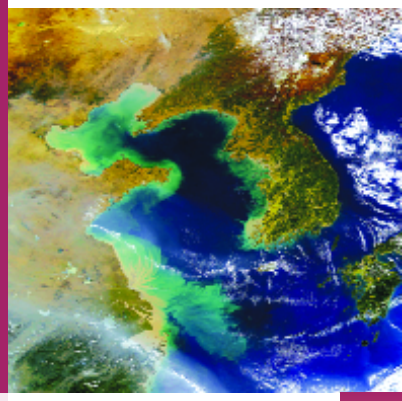
infrastructure/Inadequate compliance assurance". This is quite a serious issue. Even if the legislative base for activities affecting the Yellow Sea was perfect in the senses of both comprehensiveness and coherence, the absence and/or weakness in the mechanisms for ensuring compliance with legislation leaves open opportunities for abuse and ignorance of the law. Such weaknesses are not confined to the Yellow Sea region; they are common failings in both developed and developing countries. This root cause will be one that justifies corrective intervention irrespective of any requirement to re-examine policy and legislative circumstances.

Many of the less frequent root causes also have similarities, particularly where they relate to weakness in the regulation of specific practices such as sewage treatment and discharge, industrial wastewater discharges and other emissions from domestic and industrial sources and activities.

This sets the framework for defining the options for intervention to address the environmental problems identified within the YSLME project. As can be gathered from the previous summary of the results of causal chain analysis for the problems in each of the technical components of the project, interventions directed at the primary, secondary and tertiary causes of the identified problems, while legitimate, will, in large part, address small groups of problems having similar proximal causes. Furthermore, in view of the dominance of legislative deficiencies and poor compliance with existing legislation, such interventions will not only be piecemeal but are also unlikely to offer sustainable benefits without improvements in the policy balance between economic development, on the one hand, and environmental and biodiversity protection on the other.

Clearly, effective and lasting interventions to address a large proportion of the problems in the Yellow Sea are those that directly address the quaternary and root causes of these problems.

8. TRANSBOUNDARY VERSUS DOMESTIC PROBLEMS

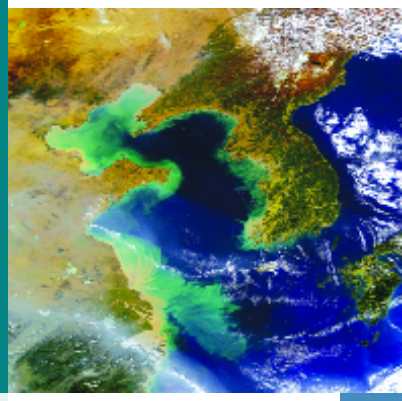


An essential component of a TDA is a review of problems and their causes to distinguish transboundary problems from those of purely national (domestic) concern. Therefore, having discussed the environmental problems and their causes but before turning to the identification and analysis of options for intervention, it is appropriate to determine if any, and which, of these problems are strictly of domestic concern only.

In the text of the previous discussion there has been reference to one domestic problem. This is the case of the adverse effects of mariculture assuming that the potential for disease transmission is among adjacent mariculture stocks and not between mariculture stocks and migratory wildfish. Problems of decreased coastal water quality in some coastal areas associated with the discharge of contaminants, particularly sewage and, heavy metals, may well constitute largely domestic problems. However, the fact that sewage contributes to the overall adverse effects associated with nitrogen discharge, which is clearly a transboundary problem, means that it cannot be dealt with purely as a domestic issue. Drawing distinctions between instances in which marine heavy metal contamination from local sources causes damage solely to resources and amenities in the same national jurisdiction, and instances in which the very continuity of marine circulation results in all discharges contributing to the burden for the Yellow Sea as a whole, can be fraught with difficulty. Essentially, therefore, all the environmental problems discussed in this TDA, other than those associated with interactions among maricultural developments, are inherently transboundary. This is the case either because the agent of adverse effect is one contributed from multiple sources in both jurisdictions or the causes of problems are associated with activities in

and around the Yellow Sea that lie in both of the riparian jurisdictions considered here. The fact that there exists a third riparian jurisdiction (the DPRK) that now has indicated a desire to participate in the YSLME project makes it preferable that contributions to the pollutant load on the entire Yellow Sea be considered a transboundary issue except in cases where the causes and consequences of pollutant releases are unambiguously within a single jurisdiction.

9. IDENTIFICATION AND ANALYSIS OF OPTIONS FOR INTERVENTION



This section of the document first identifies the options for management intervention in the Yellow Sea region based on the analysis of root causes of contemporary environmental problems. These options are then evaluated in the context of the policy and legislative circumstances in each of the riparian countries (excluding the Democratic People's Republic of Korea that is not yet a party to the Yellow Sea LME project) and associated socio-economic and technical capacity.

9.1. Identification of the Options for Intervention

The major options for intervention relate, first, to improving the coherence and comprehensiveness of legislation for the protection of the environment and biodiversity in the context of sustained economic development in both countries. This has not only the advantage of addressing the root causes of transboundary problems in the region but also dealing with similar problems in other coastal sea areas of China and the East and South Sea coastal areas of the Republic of Korea. It has the added benefit of also offering, at the same time, a means of addressing domestic problems in both countries. Addressing such legislative improvements, founded on statements of national policy regarding the balance between economic and social development and environmental protection would probably be the best approach to adopt. The regional YSLME project offers a vehicle for improving this balance in a manner that also improves the coherence of national legislation in China and the

Republic of Korea.

Various United Nations agencies have long promoted the concept of multi-sectoral management of the environment, its resources and amenities. This has led to, or been founded on, other concepts like "integrated coastal zone management" that endeavour to improve the coherence and comprehensiveness of environmental management and protection.

Full integration of the sectoral aspects of environmental management may be an unrealistic goal because the conventional structure of government administration is dominantly founded on sectorally-focussed departments and agencies. Nevertheless, making the legislative basis of environmental management a coherent one constitutes a first step towards such integration. In the Yellow Sea, there are clearly deficiencies in fisheries management and regulation. Furthermore, these deficiencies have contributed to environmental impacts or threats to biodiversity in sectors other than fisheries management.

Coherence of governmental and subordinate (i.e., regional[15], provincial and municipal) legislation constitutes an important step in resolving within-sector and cross-sectoral problems of this kind.

Legislative improvements alone will not solve the existing problems and forestall impending threats if the law is not observed. Accordingly, the second most important intervention in the region is the improvement of the legislative compliance infrastructure in both countries. Both countries need to make a commitment to ensure that their respective laws relating to marine and coastal zone development are observed. This can be done by devising and implementing a compliance assurance mechanism that monitors activities and ensures that, where appropriate, corrective measures are adopted in a timely manner. While this issue is one having wider connotations in respect to the observance of the law in all public and private endeavours, in this instance the purpose is to ensure that the laws created to protect the environment and biodiversity are fully observed. The creation of a compliance infrastructure requires the development of a routine surveillance and monitoring capacity applied to coastal zone and maritime activities that is based on sound science. It also requires that the results of such surveillance and monitoring activities are analysed and interpreted in an expedient manner to provide indications of actual or impending problems.

15 "Regional" in this context applies to regions within a country.

Once identified, these problems can then be further investigated to determine if violations of legislation have occurred and, if so, prompt corrective measures are instituted. Finally, it requires a cadre of professional staff with the ability to provide assistance to the violators to correct their activities and, in the event that the violators prove to be unresponsive, can commence appropriate legal action. For the compliance system to become respected as an authoritative and effective representative of the government, fines should be commensurate with the damage caused rather than a trivial "slap on the wrist". Furthermore, in cases where damage has been inflicted on national or regional environments or their resources or on other legitimate users of the marine environment and its resources and amenities, punitive damages should be sought from violators. Useful models for such a compliance assurance system exist in many countries.

There are also options at a lower level that would be justified by several of the individual root causes of problems. These, for example, would involve improving the regulation of particular sectors, such as industry, energy production, land development, aquaculture, mariculture and marine fisheries. Interventions applied in each of these sectors, and others, would definitely contribute to mitigating problems in the Yellow Sea but would not have the fundamental impact that the previous two types of intervention would have.

It is clear from these and other root causes, such as the "absence of a balanced energy policy based on the need to mitigate climate change and protect the environment", that there is a need for a fundamental policy review in the two countries. Indeed, such a policy review should be done as a precursor to the consideration of legislative amendments. The goal of such a policy review would be to determine how greater holisticism (i.e., coherence and comprehensiveness) might be engendered in the legislation applicable to differing sectors of the economy and national aspirations. Policy reviews in both countries could be augmented by a mutual-conducted regional overview to determine the extent to which harmonization of policies might be achieved.

Lest the preceding causal chain process leading to the identification of the root causes of problems be regarded as a somewhat academic exercise reflecting only the views of scientists,

> *there is useful confirmation in the stakeholder opinion analysis included in the national governance review conducted by China. The proportion of coastal residents that took the view that*

weak administration was a primary cause of environmental problems in the Yellow Sea was 54% with the largest sub-cause being poor cooperation among government departments. This clearly reflects the public view that there is both a lack of holisticism and poor enforcement of legislation.

This is compounded by the fact that more individuals would tend to report legal violations to the press or to ignore them rather than report them to government agencies. However, it should be remembered that public perceptions of problems are often not very objective. For example, while there may be justification for litter occupying the dominant place in public opinion as reflected by the Chinese governance review, there is little substantiation for the attribution of problems by the public to phosphorus-containing detergents. On the other hand, it is heartening to find a dominant opinion among all stakeholder group responses that 61% consider that scientists constitute the major source of influence on governments regarding policy and legislative development in relation to the exploitation and protection of the marine environment. In a sense, this majority view suggests that the public would be likely to have confidence in the results of this TDA because it is based primarily on scientific considerations.

9.2. Analysis of the Options for Intervention

An analysis of the options for intervention can only be carried out in the context of the policy, legislative and administrative circumstances prevailing in the country parties to this project, i.e., in the People's Republic of China and the Republic of Korea. Fortunately, reviews of the governance in these countries have been carried out as part of the preparative work for the development of a Strategic Action Programme for the Yellow Sea. These reviews can be used as a basis for critically examining the options for intervention to address contemporary environmental and biodiversity problems and threats in the region.

Interventions directed at the lower levels of cause, such as tightening the regulation of particular user sectors (e.g., fisheries, land reclamation, coastal construction, industrial discharges, sewage treatment, mariculture, aquaculture, river catchment engineering and land reclamation) would clearly be easier to implement than interventions addressing the most

common root causes. This is because sectoral approaches to administration, regulation and management are entrenched in both countries. Accordingly, the design and implementation of such interventions would lie primarily with individual government agencies and their provincial counterparts or subordinates. This, however, would not excuse the departments concerned from undertaking detailed consultations with other government departments and other stakeholders prior to any decision to adopt a particular intervention. The fact that cooperation among federal departments and agencies is not always perfect (a view clearly expressed by the scientists involved in this project and those consulted during the preparation of the Chinese governance review, including the public) constitutes a drawback to these rather piecemeal interventions. In other words, they are relatively simple interventions to conceive and promulgate but would not have the magnitude of benefit or degree of public confidence that could be obtained through the adoption of more fundamental interventions.

At the next highest level, the most obvious intervention to be considered is the improvement of the compliance assurance mechanisms associated with legislation and regulation. Again, these would have the advantage of lying predominantly in the domains of individual federal government departments. Adoption of interventions to improve compliance assurance in all sectors of coastal zone and marine resource exploitation sectors would constitute a much more fundamental kind of intervention compared with that discussed in the previous paragraph. Furthermore, it is one in which all stakeholder departments can play a role and it might also have the advantage of promoting greater inter-departmental cooperation.

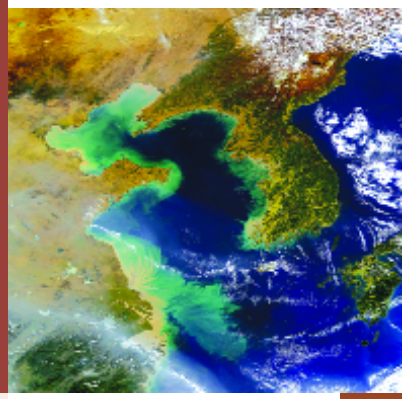
Interventions aimed at addressing predominant root causes of the environmental problems in the Yellow Sea will, as already stated, offer the greatest potential benefits to the environment and define a comprehensive, coherent and sensible framework for coastal and marine exploitation activities. It is, however, the most difficult of the interventions to design and implement. It inherently requires full and constructive cooperation among stakeholders in all sectors, including government, to devise a consistent national legislative and regulatory framework. The fact that there are two countries involved, and ideally a third, the DPRK, adds an extra dimension of complexity. If this fundamental approach were to be adopted for the preparation of the Strategic Action Programme for the Yellow Sea LME, it should be preceded by comprehensive policy reviews in

China and the Republic of Korea involving stakeholders at the highest levels of government.

Interventions addressing lower levels in the causal chains have also been considered. There are two obvious instances in which actions could be adopted to address intermediate causes: first, the introduction of buffer zones between agricultural activities and freshwaters to reduce the runoff of agricultural contaminants including pesticide and fertilizer residues and animal sewage; and, second, the imposition of requirements for prior environmental impact assessments for coastal zone developments above a certain scale that could be determined during the consultations leading to SAP development.

Finally, there are a number of scientific activities that could be undertaken to provide long-term benefit to the management of the region. These include the harmonization of fish stock management mechanisms between China and Korea, the wider adoption of the polyculture approach to mariculture as a means of reducing stress on coastal areas, and practical application of the assimilative capacity concept to determining the acceptable rates of aggregate contaminant release to coastal embayments and the Yellow Sea as a whole.

10. OTHER ISSUES WORTHY OF CONSIDERATION DURING THE PREPARATION OF THE SAP FOR THE YELLOW SEA LME



During the process of preparing the national reports and regional syntheses for each of the technical components of the project (pollution, ecosystem, fisheries and biodiversity) a number of observations have been made regarding various deficiencies in environmental management and biodiversity protection. Many of these additional issues are of an administrative and organizational nature but are worth recording to determine whether they are inherently covered by the root causes and/or the potential interventions for mitigating these causes that have already been discussed. Some of the project component syntheses include recommendations relating to the need for new approaches or the correction of various deficiencies[16] . All such observations and recommendations, to the extent that they do not duplicate the conclusions of the causal chain analyses, are documented here as additional considerations for Strategic Action Programme development.

The **regional synthesis for pollution** (YSLME 2006c) contains a number of recommendations in various categories. Under the heading "Designation of pollution hot spots and sensitive areas for the SAP" the following recommendation is made:

The Strategic Action Programme (SAP) will be an action-oriented YSLME initiative to tackle and eliminate pollutants of terrestrial origin by facilitating and accelerating the implementation of national environmental goals. It needs to identify pollution hot spots and sensitive areas that are the sources of effluent that result in the introduction of toxic, persistent and bio-accumulative pollutants into the Yellow Sea. Based on the available pollution data and information

16 Subsequent quotations extracted from the four regional syntheses have been edited for clarity.

generated through the national and cooperative study cruise reports, pollution hot spots in the Yellow Sea can be identified and ranked. This provides a basis for identifying areas to be specially managed and protected to preserve the marine ecosystem and protect public health.

Under the heading "Baseline contaminant levels essential to protecting the safety of marine life" the following recommendation is made:

Threshold concentrations for safe levels of conservative pollutants should be specified. Priority should be given to those pollutants posing the greatest threat to the marine environment and commercially important plants and animals living there.

Finally, the following recommendations are made and specifically directed to stewardship agencies and organizations:

- Develop management strategies from simple to comprehensive and from short-term to long-term focusing on sustainable production and the safety of marine products;
- Urge the use of scientific findings and assessments to identify and evaluate management options in the context of both scientifically credibility and economic practicality in relation to the use of ecosystem goods and services of the Yellow Sea;
- Countries should undertake transboundary diagnostic analyses (TDAs) to provide the science-based assessments for priority setting in respect to threats to the ecosystem and their root causes[17]; and
- Science-based assessments should lead interested countries to advance new policies and actions for eliminating the root causes of transboundary environmental and resource use practices leading to serious degradation of coastal environments and losses in biodiversity and food security resulting from the overexploitation of fish population in the Yellow Sea Large Marine Ecosystem.

These recommendations raise two subjects not covered by the previous root cause analysis. These are "hot spots" and "environmental quality standards (EQSs)". It would appear that the term "hot spots" is used to refer to intense sources of contaminant discharge at the coast. This same term is often used to refer to heavily contaminated sites in the environment itself but this does not correspond to the intent here. If a coherent, comprehensive and balanced system of regulation is applied to all forms of activity that potentially affect the marine environment in response to

17 This entry is assumed to be an exhortation to single countries to apply TDA to national (i.e., domestic) problems.

the results of root cause analysis, it would automatically address the problems associated with a combination of contaminant discharges at the coast.

The issue of environmental quality standards is largely peripheral to the kinds of problems identified in the Yellow Sea. They can be used as a monitoring benchmark to identify instances in which the concentrations of substances in water are sufficiently abnormal either to warrant an investigation of their cause or the adoption of remedial action if the cause is known. Such standards need not be restricted to contaminant concentrations but can be applied to a wide range of water and sediment constituents as a guide to conditions in a given area. Depending on their purpose, however, EQS values for contaminants can be difficult to define in a manner that intrinsically reflects some level of safety. This is because current knowledge of exposure and effects imposes limits on the degree to which a particular concentration can be regarded as "safe". Indeed, the term "safe" in respect to the effects of exposure on non-human organisms usually corresponds to a judgement of "acceptability". While this can often be considered from predominantly scientific perspectives, it invariably depends, as in the case of human health protection, on a prior definition of acceptability from policy perspectives.

The **regional synthesis for ecosystems** (YSLME 2006d) includes a list of major information deficiencies as shown in Table 18. Its recommendations are limited to providing guidance on the means of overcoming such deficiencies for the improvement of future assessments.

Table 18. Data and Information Gaps Relating to the Yellow Sea Ecosystem

Topic	Data and Information Gaps
Phytoplankton	Species composition - seasonal species composition except autumn - detailed species composition for each taxonomic group Abundance - winter data, - detailed data on diverse taxonomic group such as picoplankton - chlorophyll-a Primary production - winter and summer production
Zooplankton	Detailed species composition for all zooplankton groups Species composition in other seasons than May and December Depth distribution of zooplankton
Benthos	Species level identification for all taxonomic groups Seasonal data except September
HABs	Species composition Detailed abundance on other taxonomic groups such as picoplankton Detailed species composition of picoplankton groups

While these recommendations are salient to the conduct of future scientific activities in the region, they are of limited relevance to policy and regulatory matters and therefore are not discussed further in this document. They could, however, be included in any future scientific activities conducted within the YSLME project or under other auspices.

The **regional synthesis for fisheries** (YSLME 2006e) also noted some issues of a technical nature that justified attention. In particular, the assumption of different sizes of some fish at maturity by the two countries presents an obstacle to harmonized fisheries management. The synthesis contains recommendations for systematic surveys to improve the understanding and prediction of fish stocks. It also notes that only general descriptions have been provided by China and Korea regarding the socio-economic aspects of fisheries without the detailed analyses required for long-term data interpretation. There is therefore a need to collect long-term data on fisheries economics and to include additional expertise on economic data analysis in future assessments.

Finally, it is recommended that a joint fisheries database be established, not only for provision of historical fisheries data and information but also as a basis for future cooperative research studies in the Yellow Sea. Such a database would be of great assistance to scientific activities for collecting and retrieving research

data and for monitoring the status of fisheries resources. This is clearly an issue that should be addressed in devising improvements to, and harmonizing, fisheries management procedures in the region.

The **regional synthesis on biodiversity** (YSLME 2006f) makes no specific recommendations. Nevertheless, there are references in the report to concerns regarding the decline of endemic species and the loss of genetic diversity although associated causal chain analyses have not been conducted. These may well be topics worthy of greater attention in the next phase of the YSLME project.

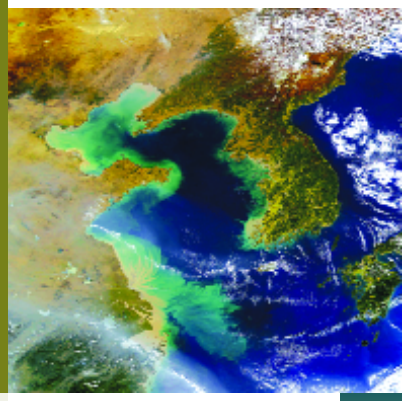
The regional synthesis on biodiversity contains the following concluding statement that is worth reproducing here.

The exceptional importance of the biodiversity of the Yellow Sea, both on a global scale and as a resource shared by China, the DPRK and the ROK, makes it highly desirable that conservation be implemented on an ecoregional basis. The challenge is to facilitate a process in which a Yellow Sea Ecoregion management plan is adopted and implemented by the three governments[18]*. Only then will the future of the globally important biodiversity of the Yellow Sea be improved and the sustainable development of society and the economy in the ecoregion achieved.*

This statement makes a plea for an environmental management plan to be developed specifically for the Yellow Sea because of its global and regional importance in a biodiversity context. This may well be a laudable suggestion. However, it can only be achieved on the basis of a sound and coherent legislative and regulatory system for resource and environmental management as argued in the identification and analysis of options for intervention based on the results of causal chain analysis in this TDA.

18 The term "three governments" is used to refer to the governments of the People's Republic of China, the Republic of Korea and the Democratic People's Republic of Korea.

11. CONCLUSIONS



A Transboundary Diagnostic Analysis (TDA) is an intermediate vehicle for the preparation of a Strategic Action Programme (SAP). This TDA has been prepared to provide guidance for the development of a SAP for the Yellow Sea that constitutes the next stage of the UNDP/GEF Yellow Sea LME project.

There is abundant evidence of changes in the condition of the Yellow Sea, some of which are the result of human activities in the region.

While the Yellow Sea is far from "dead", as some authors have claimed (Cha and Hwang, 2005), there are signs of change some of which can be directly attributed to shortcomings in human behaviour, weaknesses in legislation and non-compliance with legal and regulatory restrictions. These are all deficiencies that should be addressed in the Yellow Sea Strategic Action Programme.

Other changes are merely worrying in the sense that their ultimate cause and long-term consequences are not fully understood from scientific perspectives. Some of these may be warning signals of responses to global climatic change but this is not in all cases certain.

This TDA shows that the most important interventions to incorporate into the Yellow Sea SAP are improvements to legislation and associated regulations in the People's Republic of China and the Republic of Korea. Such improvements should be aimed at enhancing the protection of marine and coastal biodiversity and the marine environment of the Yellow Sea, its resources and amenities. Specifically, efforts need to be directed to improving both the comprehensiveness and coherence of legislation so that existing gaps and loopholes are closed. Moreover, to the extent possible, the legislative, administrative and regulatory frameworks in the People's Republic of

China and Korea should be harmonized to provide a "level playing field" for human activities within, and on the borders of, the Yellow Sea. To this end, a comprehensive and critical review of the existing legislative provisions in the two countries should be undertaken as a means of examining opportunities for improving the protection of the Yellow Sea environment and its biodiversity and promoting the comparability of controls on human activities in the two countries.

In this context, the two riparian states might wish to consider a bilateral agreement, either independently or under a regional umbrella organization, to cooperate in the enhancement of their legislative and regulatory provisions for the protection of the Yellow Sea. Such an agreement could constitute a basis of a Strategic Action Programme that would include reviews of legislation and an agreement to foster the harmonization of laws and regulations, first domestically and then bilaterally.

The second most important topic for inclusion in the SAP would be an agreement to improve the level of compliance with laws and regulations in all sectors of human activity having the potential to adversely affect the Yellow Sea. Currently, there exist deficiencies in the extent of compliance with laws and regulations. This is most evident in the marine fisheries sector. The causal chain analysis in this TDA shows, however, that similar problems of non-compliance with legal and regulatory provisions are occurring in other sectors. The creation of a comprehensive compliance assurance mechanism in both countries would clearly provide substantial benefits to the environment and the protection of biodiversity.

It should be noted, that full implementation of the Ballast Water Convention, the Stockholm Convention, and the new provisions (Annex V) of the MARPOL Convention will provide increased protection of the Yellow Sea from the perspectives of the introduction of alien species, the management of persistent organic pollutants and the mitigation of solid wastes derived from the maritime transport sector. The SAP should concentrate on complementary initiatives to these developments as a means of reducing stress on the Yellow Sea from other sources and activities.

There are two issues to which interventions directed at lower levels in the causal chains would be both tractable, sensible and offer substantial benefits. The first of these addresses agricultural runoff from both arable farming and animal husbandry. Fertilizers, animal sewage, pesticides and considerable quantities of nutrients are derived from agricultural activities and there would be considerable benefit in reducing such runoff. This can be done by imposing buffer zones between

farms and adjacent surface waters, such as streams lakes and rivers, to absorb some of the contaminants. The inclusion of a programme to steadily introduce additional buffer zones between farms and freshwater bodies could be included in the SAP. The second intervention that might be considered is more generic – the application of environmental impact assessments (EIA) to future coastal zone developments as a means of ensuring that all potential interactions with, and effects on, existing activities, resources and amenities are considered prior to the endorsement new developments. The scale of development for which EIA would be required could be determined by the two riparian states during the course of the SAP preparation process.

The TDA also reveals that there are some other largely technical, measures that could be adopted to reduce stress on the Yellow Sea. The final paragraphs below specify particular technical, engineering and/or scientific activities that should be included as elements of a technical component of the Yellow Sea SAP. They deal respectively with improved solid waste management, harmonization of fish stock assessment techniques, the wider application of the polyculture concept in maricultural development, and the application of the concept of assimilative capacity to ensure that sensible limits are placed on riverine and coastal discharges to the Yellow Sea and on the scale of coastal developments, such as mariculture.

The two countries should consider making a stronger commitment to improving solid waste management in all sectors of human activity, especially the construction and municipal sectors, as a means of reducing the entry of floating and submerged solid waste into the marine environment where it interferes with both recreational and fishing activities and can present hazards to navigation.

Harmonization of the scientific basis for the management of individual fish stocks would improve the consistency of fisheries management in both China and Korea. It would also provide a vehicle for harmonizing the marine natural resource management frameworks between the two countries.

The polyculture approach to mariculture, in which pelagic fish, molluscs and seaweeds are grown in sequence along the prevailing current direction in coastal areas, is worthy of wider application as a means of minimizing the adverse effects and maximizing the benefits of mariculture. The polyculture concept would appear to warrant testing in coastal areas to determine the optimum density and mix of organisms that can be cultured in sequence as a function of water advection rates.

It is abundantly clear from this TDA, and other assessments of the region (e.g.,

GIWA 2005), that pollution (that is, adverse effects associated with substances introduced to the Yellow Sea from municipal, industrial, maricultural and agricultural activities) is a major cause of environmental compromise, particularly in inshore and coastal areas. The concept of assimilative capacity applied to coastal embayments and other coastal areas of the Yellow Sea, and the Yellow Sea itself, offers an ability to determine acceptable limits for the aggregate discharges of substances like sewage and nitrogen that are clearly having serious adverse effects on the marine environment. The scientists engaged in the UNDP/GEF Yellow Sea project have both the expertise and capacity to undertake calculations that would provide discharge limits for such substances and others that have the potential for similar adverse effects. It should be possible to calculate the assimilative capacity of coastal embayments and the Yellow Sea as a whole. This can then be used to define the rates and locations of contaminant discharge and the scales and locations of maricultural activities that are sustainable in the context of their compatibility with other uses of the sea. Such work would improve national capacities in China and Korea for the implementation of the provisions of the Global Programme of Action to Protect the Marine Environment from Land-based Activities (UNEP, 1995).

One of the outstanding scientific and management challenges is the protection of biodiversity through the medium of habitat preservation. It would appear that the World Wide Fund for Nature, together with its Korean scientific institute partners (WWF et al., 2006) has made a commendable attempt to define the areas, animals and plants worthy of primary protection. Future work in the biodiversity component of the project should consider building on this work by devising ways to protect these areas and resources. Such measures, once devised, might also be included among the interventions in the Strategic Action Programme for the Yellow Sea.

Finally, a comment needs to be made about future scientific work conducted in the YSLME project. There would be benefit in revising the existing scientific working group structure, originally created in alignment with the project components, to one that allows issues to be investigated more from multi-disciplinary, rather than single disciplinary, perspectives. The Project Management Office might consider consulting the Project Steering Committee on this topic during the early phases of the consultations on the development of the Yellow Sea SAP.

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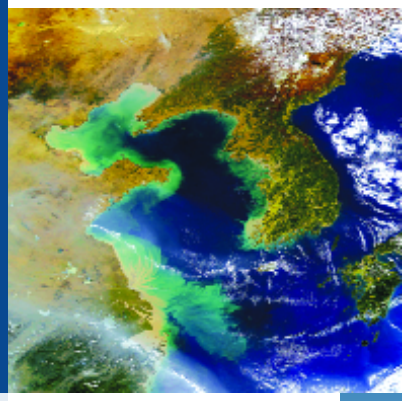

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19 In the case of members of the PMO, names are written according to the western convention (forename, family name) with family names given in capital letters. In all other cases, names are expressed in either western convention or Chinese/Korean convention as appropriate to the country of origin of the individuals but, similarly, with all family names given in capitals.

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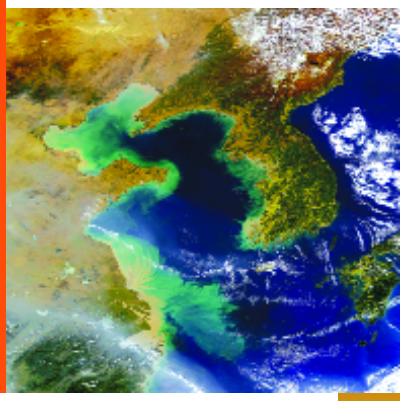

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