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Management for the Seas
of East Asia

Department of
Environment and
Natural Resources

Manila Bay Initial Risk Assessment

April 2001

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MANILA BAY: INITIAL RISK ASSESSMENT

April 2001

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MISSION STATEMENT

The Global Environment Facility/United Nations Development Programme/International Maritime Organization Regional Programme on Building Partnerships in Environmental Management for the Seas of East Asia (PEMSEA) aims to promote a shared vision for the Seas of East Asia:

> "The resource systems of the Seas of East Asia are a natural heritage, safeguarding sustainable and healthy food supplies, livelihood, properties and investments, and social, cultural and ecological values for the people of the region, while contributing to economic prosperity and global markets through safe and efficient maritime trade, thereby promoting a peaceful and harmonious co-existence for present and future generations."

PEMSEA focuses on building intergovernmental, interagency and intersectoral partnerships to strengthen environmental management capabilities at the local, national and regional levels, and develop the collective capacity to implement appropriate strategies and environmental action programs on self-reliant basis. Specifically, PEMSEA will carry out the following:

- build national and regional capacity to implement integrated coastal management programs;
- promote multi-country initiatives in addressing priority transboundary environment issues in sub-regional sea areas and pollution hotspots;
- reinforce and establish a range of functional networks to support environmental management;
- identify environmental investment and financing opportunities and promote mechanisms, such as public-private partnerships, environmental projects for financing and other forms of developmental assistance;
- advance scientific and technical inputs to support decision-making;
- develop integrated information management systems linking selected sites into a regional network for data sharing and technical support;
- establish the enabling environment to reinforce delivery capabilities and advance the concerns of non-government and community-based organizations, environmental journalists, religious groups and other stakeholders;
- strengthen national capacities for developing integrated coastal and marine policies as part of state policies for sustainable socio-economic development; and
- promote regional commitment for implementing international conventions, and strengthening regional and sub-regional cooperation and collaboration using a sustainable regional mechanism.

The eleven participating countries are: Brunei Darussalam, Cambodia, Democratic People's Republic of Korea, Indonesia, Malaysia, People's Republic of China, Philippines, Republic of Korea, Singapore, Thailand and Vietnam. The collective efforts of these countries in implementing the strategies and activities will result in effective policy and management interventions, and in cumulative global environmental benefits, thereby contributing towards the achievement of the ultimate goal of protecting and sustaining the life support systems in the coastal and international waters over the long term.

Dr. Chua Thia-Eng
Regional Programme Director
PEMSEA

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List of Abbreviations and Acronyms

ASEAN	Association of Southeast Asian Nations
BFAR	Bureau of Fisheries and Aquatic Resources
BOD	biochemical oxygen demand
COD	chemical oxygen demand
CPUE	catch per unit of effort
DAO 34	DENR Administrative Order No. 34
DENR	Department of Environment and Natural Resources
DO	dissolved oxygen
EIA	environmental impact assessment
EMB	Environmental Management Bureau
FSP-REA	Fisheries Sector Program – Resource and Ecological Assessment
FNRI	Food and Nutrition Research Institute
Geomean	geometric mean
IRA	initial risk assessment
ISQV	interim sediment quality values of Hong Kong
LC_{50}	concentration of toxicant that causes death in 50% of an exposed population
LOAEL	lowest observable adverse effect level
LOC	level of concern
MEC	measured environmental concentration
MEL	measured environmental levels
MEY	maximum efficiency yield
MPN	most probable number
MSY	maximum sustainable yield
MWSS	Metropolitan Water and Sewerage System
NH_3	ammonia
NO_3	nitrate
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorobiphenyls
PCG	Philippine Coast Guard
PEC	predicted environmental concentration
PEL	predicted environmental levels
PEMSEA	Partnerships in Environmental Management for the Seas of East Asia
PNEC	predicted no-effects concentration
PNEL	predicted no-effects level
PO_4	phosphate
PRRP	Pasig River Rehabilitation Project
PSP	paralytic shellfish poisoning
RQ	risk quotient: MEC (or PEC)/PNEC (or Threshold)
$RQ_{Geomean}$	mean risk quotient: MEC (or PEC) $_{Geomean}$/PNEC (or Threshold)
RQ_{Max}	maximum risk quotient: MEC (or PEC) $_{Max}$/PNEC (or Threshold)
SEMP	strategic environmental management plan
TBT	tributyltin
TDI	tolerable daily intake
TPAH	total polycyclic aromatic hydrocarbons
TSH	total saturated hydrocarbons
TOC	total organic carbon
TSS	total suspended solids
USFDA	United States Food and Drug Administration
USEPA	United States Environment Protection Agency

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Executive Summary

Environmental risk assessment estimates the likelihood of harm being done to identified targets as a result of factors emanating from human activity, but reaching the targets through the environment. This combines knowledge about the factors that bring about hazards, their levels in the environment, and the pathways to the targets.

The potential harm to human and environmental targets may arise from exposure to contaminants in the environment. These contaminants come from activities that bring economic growth and contribute benefits to society. There can be two approaches to protect the environment and human health. One approach is to eliminate the contaminant or stop the activity that produces it. Another approach is to prevent the contaminant level from exceeding an allowable level that presents acceptable risk. Elimination of contamination to zero concentration may require large investments, and discontinuing economic activities may hinder the delivery of goods and services that contribute to human welfare and economic development.

The second approach, the risk-based methodology, presumes that there are contaminant levels in the environment that present low or acceptable risks to human health and the environment, and that there is not always a need for zero emission levels. Scientific studies have specified threshold values below which adverse effects are not likely to occur. These studies also present possible consequences for contaminant levels that exceed the threshold values. This implies that economic development activities can be managed at levels that promote human health and environmental protection, yet maintain activities that produce economic benefits. This emphasizes the importance of cost-benefit analyses in sustainable development initiatives.

Potential harm to environmental targets may also arise from indiscriminate extraction of resources and physical destruction of habitats. The environmental impacts of these activities stem from the loss of ecological functions and consequent disruption of ecological balance. The impacts may not be as evident as impacts from pollutants but could be irreversible and may lead to greater losses. Risk assessment evaluates the consequences of these activities and weighs the adverse effects to the environment against the contributions to economic development and benefits to society.

The risk assessment attempted to answer two questions: "what evidence is there for harm being done to targets in the bay?" (referred to as retrospective risk assessment) and "what problems might occur as a consequence of conditions known to exist, or possibly exist in the future?" (referred to as prospective risk assessment).

To answer these questions, it is necessary to identify appropriate targets, assessment endpoints, and corresponding measurement endpoints. Assessment endpoints are features related to the continued existence and functioning of the identified targets such as community structure or diversity, production, density changes and mortality. These, however, may not be easy or would take much time to measure. So other features related to the assessment endpoints and which are easier to measure are used instead.

These are called measurement endpoints. For the earlier mentioned assessment endpoints, the corresponding measurement endpoints are presence of indicator species (for community structure/diversity), biomass (for production), abundance (for density changes), LC_{50} or biomarkers (for mortality) (MPP-EAS, 1999a).

The initial risk assessment of Manila Bay was conducted as a preliminary step to the refined risk assessment. It provides a glimpse of environmental conditions in the bay using available secondary data. It serves as a screening mechanism to identify priority environmental concerns in the bay, identify data gaps and uncertainties and recommend areas for immediate management intervention or for further assessment. It identifies contaminants that present acceptable risks and hence, may not need further assessment, and highlights contaminants that present risks to the environment and/or to human health. It also identifies resources and habitats that are at risk and recognizes significant causes of risks. The results of the initial risk assessment will be used to formulate an action plan for a more comprehensive risk assessment that is focused on the identified priority areas of concern. Evaluating the results of the initial risk assessment will also facilitate improvement and refinement of the methods used.

The initial risk assessment also draws attention to the importance of collaboration among different government agencies, universities and scientific and technical research institutions and the roles that these groups may undertake in the risk assessment. The wide range of expertise and knowledge of these different groups would contribute to the efficient conduct and success of the risk assessment. A mechanism to facilitate sharing of information and access to existing data should also be put in place.

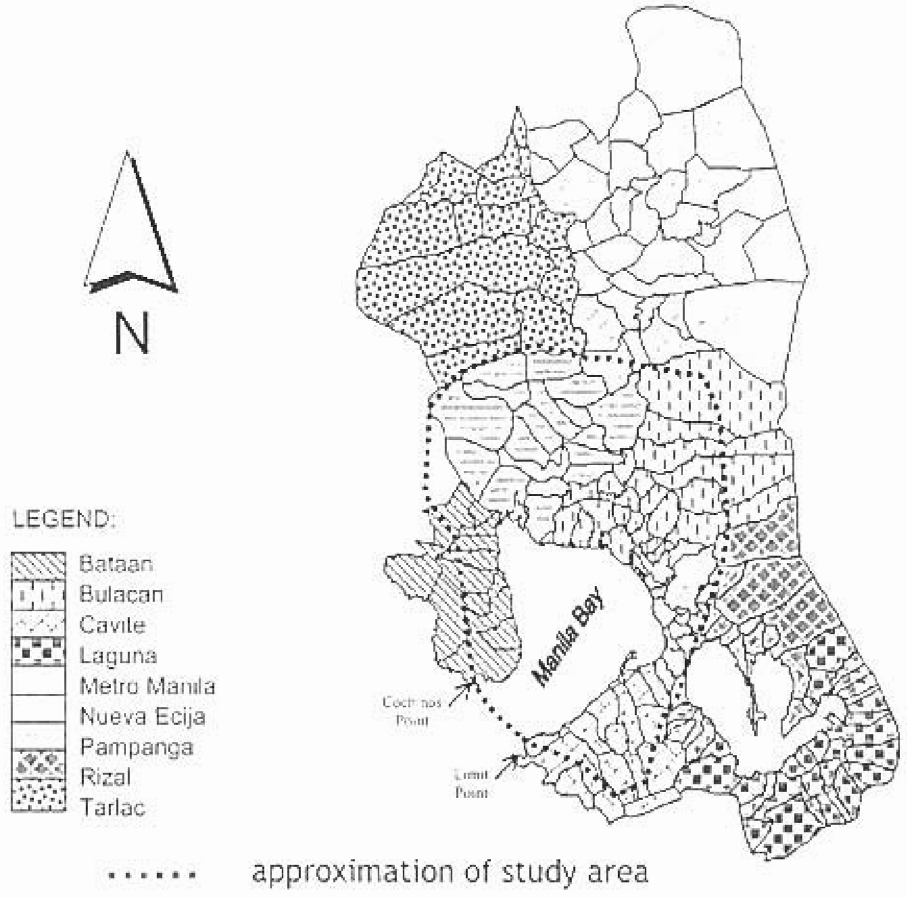
In the refined risk assessment, the methodologies, conclusions and recommendations in the initial risk assessment will be verified and, if possible, updated. The assessment will be focused on the identified human health and ecological issues. More in-depth characterization of contamination with respect to spatial distribution will be conducted geared at identifying hot spots and determining the relative contribution of various sources of contamination. Predicting the levels and distribution of contaminants will be made possible by employing models that incorporate information on contaminant releases, inputs from tributaries and major point sources, fate of pollutants and the hydrodynamics of the bay. More sophisticated techniques will also be used to improve uncertainty analyses. And, for parameters for which data are not available, the refined risk assessment will include a systematic collection of primary data.

The results of the risk assessment – what is at risk and how it can be protected against the risk – are essential to ensure its sustainability. It gives management decisions a certain degree of confidence and it is hoped that refinement will provide resource managers the opportunity to predict specific ecological changes brought by specific stressors for use in alternative management decisions. Risk assessment as a management tool is expected to play a significant role in strengthening marine pollution risk management.

In risk management, options for addressing priority environmental concerns are identified. The benefits and costs to society of employing the identified management options are considered as well as stakeholder consensus on appropriate management interventions. The approved risk management interventions will be incorporated in the Strategic Environmental Management Plan (SEMP) for Manila Bay.

The initial risk assessment of Manila Bay began with the delineation of the boundaries of the bay as study area for the risk assessment. The study area and administrative boundaries are presented in the following figure.

The Administrative Boundaries (LGUs) and Study Area of the Manila Bay Project



Manila Bay is a semi-enclosed estuary which is connected to the South China Sea via a 16.7 km-wide entrance (PRRP, 1999). It covers three regions: Region III, Region IV and the National Capital Region (NCR) and is bordered by NCR and the provinces of

Bataan, Pampanga, Bulacan and Cavite. It receives drainage from approximately 17,000 km^2 of watershed consisting of 26 catchment areas. The catchment area is bounded by the Sierra Madre mountain range to the east, the Caraballo mountains to the north, the Zambales mountains to the northwest and the Bataan mountains to the west (BFAR, 1995).

Manila Bay has a coastline of approximately 190 km and a surface area of about 1,800 km^2. It consists of a gently sloping basin with the depth increasing at a rate of 1 m per km from the interior to the entrance and has an average depth of 17 m (PRRP, 1999).

The population in the overall drainage area, as of 1995, is approximately 16 million (NSO, 1996). Economic activities in catchments and around the perimeter of the Bay range from fishing and agriculture to a variety of industries including an expanding petrochemical sector.

The study area consists of the immediate watersheds draining into Manila Bay through tributaries and major river waterways (area delineated with dashed lines). It covers almost the whole of the Cavite, Bulacan, and Pampanga provinces, as well as, National Capital Region, and about half of the province of Bataan. This includes the municipalities found within an area that starts off at the Limit Point in Cavite, covering almost the whole province as its watersheds start to drain from the Tagaytay Ridge that is found in the south easternmost part of the province. The study area also covers the cities and municipalities of the National Capital Region, except for portions of a few municipalities that have waterways that drain into Laguna Lake. The provinces of Bulacan and Pampanga are also part of the study area since the rivers and waterways found in both provinces eventually drain into the bay. In the province of Bataan, headwaters of rivers start from the mountainous and hilly areas of the Mt. Natib and Mt. Mariveles and other smaller mountain and hill ranges which form a ridge that almost divides the Bataan peninsula into two up to Cochinos Point in Mariveles, Bataan, with one half of the province draining into the bay and the other half into the South China Sea.

The results of the retrospective and prospective risk assessments are summarized in the following sections.

RETROSPECTIVE RISK ASSESSMENT

In the retrospective risk assessment, qualitative and quantitative observations on the resources and habitats were assessed in reference to earlier observations to determine if there are significant changes, particularly decline. Potential agents were identified and the likelihood that these agents caused the impacts on the resources and habitats were determined.

Data for the retrospective assessment were mostly taken from the Resource and Ecological Assessment of Manila Bay (BFAR, 1995) that was completed in 1995 under the Fisheries Sector Program of the Bureau of Fisheries and Aquatic Resources (FSP-BFAR). Other sources of information include the Philippine Journal of Fisheries of

BFAR, the compilation of studies and reports from the Tambuyog Development Center (1990), and the reports prepared by the Department of Environment and Natural Resources (DENR) Region 3 (1999) and National Capital Region (1999) on the watershed of Manila Bay within their respective jurisdictions.

The resources considered include: 1) fisheries, 2) shellfisheries, 3) seaweeds, and 4) phytoplankton. For habitats, the following were assessed: 1) mangroves, 2) coral reefs, 3) seagrass beds 4) soft-bottoms, 5) mudflats, 6) sandflats and beaches, and 7) rocky shores.

Results

A clear evidence of decline based on research information (BFAR, 1995; Tambuyog Development Center, 1990; and FSP-DA, 1992) was established for fisheries, shellfisheries and mangroves. For coral reefs, there were no records of the previous extent of cover but there were unpublished accounts indicating that there has been a decline in the quality and cover of the reefs.

For fisheries and shellfisheries, the identified primary agents were overfishing or overcollection and the use of destructive fishing methods. Discharges from land- and sea-based activities have also brought adverse ecological effects that may have contributed to the decline in these resources, especially for shellfish. This is evidenced by the low dissolved oxygen (DO) in the water column indicating increased oxygen demand on the bay for degradation of organic inputs. The low DO has been suspected as the major cause of decline in the benthos, which has consequent adverse effects on organisms at higher trophic levels that are supported by the benthic community. Exposure to toxic contaminants in the water column may also have adverse effects on the reproductive processes and growth of these resources. Another factor that has contributed to the decline in fisheries/shellfisheries is the destruction of habitats such as mangroves and corals that has led to the loss of their ecological functions as breeding, spawning and nursery grounds for various marine life.

For shellfisheries, it is important to note that although overcollection was identified as the most likely agent for the decline, several factors need to be considered in interpreting production data and attributing causes of decline. These factors include the distinction between collections from culture farms and from the wild, and the possible effects of the red tide episodes on the demand for shellfish from the bay.

The primary factors identified in the decline of mangrove cover were physical removal for various purposes such as reclamation for development projects, conversion to fishponds and collection for alternative livelihood. The effects of pollution cannot be disregarded but this is not as significant as the impact of the identified primary agent. There were reports of pest infestation that has contributed to the decline but this was localized and may be one of the manifestations of the effects of pollution. An ecosystem (e.g., mangrove) under stress may be susceptible to various pests.

The decline in coral cover was attributed to physical destruction from collection activities and from improper fishing practices as well as smothering of the corals due to increased sedimentation from reclamation and other land use conversion activities. The levels of some chemical contaminants in the water column and sediments may also have contributed to the decline.

Phytoplankton is an important resource that supports higher trophic levels in the bay. There were no available data that could be used to ascertain if this resource is at risk but data on chlorophyll-a, an index of primary productivity was available. Based on the increasing trend of chlorophyll-a concentrations and also the elevated levels of nutrients that are required for primary production, it was obvious that phytoplankton is not at risk in the bay. On the contrary, it should be treated as an indicator of ecological problems (as signal of eutrophication and harmful phytoplankton blooms).

For other resources and habitats, retrospective risk assessment could not be performed due to lack of information on previous extent of cover and distribution in the bay.

PROSPECTIVE RISK ASSESSMENT

In the prospective risk assessment, potential stressors in the area of interest were identified and the measured environmental concentrations (MECs) of these stressors were compared with threshold values or predicted no effect concentrations (PNECs) to obtain risk quotients (RQs). An RQ less than one indicates acceptable risk and suggests little concern while an RQ greater than one signifies cause for concern. The level of concern increases with increase in RQ.

The primary source of information for the prospective risk assessment was the Pasig River Rehabilitation Program Report (PRRP, 1999). Other references that were used include the Fisheries Sector Program – Resource and Ecological Assessment of Manila Bay (BFAR, 1995), the Report of the Manila Bay Monitoring Project (EMB-DENR, 1991), the Philippine Environmental Quality Report for 1990-1996 (EMB-DENR, 1996), and several published articles from scientific journals and proceedings. A detailed list of the sources of data for each parameter is given in Appendix 2. It includes descriptions of the data and sampling stations.

Most of the data used were presumed to be accurate and reliable although preliminary screening was done for some data for which ranges of concentrations in different environmental conditions are known.

The PRRP (1999) study was conducted from 1996 to 1998. The study covered 10 monitoring stations for water column parameters every month and 10-18 stations for sediment parameters twice a year. These stations were spread across the entire bay. The monitoring stations for tissue parameters were limited to Bulacan, Parañaque and Cavite. The other studies covered nearshore stations around the bay or some sections of the bay only.

The PRRP (1999) study provided the most extensive spatial study of the water column and sediments. The stations covered, were, however, still limited and may not represent conditions in the entire bay. The PRRP sampling stations for water quality, sediment and shellfish tissue are presented in Appendix 3 (a – c), along with the sampling stations for PAHs in sediments from a separate study (Santiago, 1997).

The threshold values or PNECs for water quality were from the Water Quality Criteria for Coastal and Marine Waters in the Philippines (DAO 34, 1990), ASEAN-Canada Proposed Marine Water Quality Criteria (Jusoh et al., 1999), US-EPA Quality Criteria for Water for regulatory purposes (US-EPA, 2000) and the Chinese Standards for Different Classifications (National Standards of P.R. China, 1995).

For sediments, the PNECs were taken from the Hong Kong Interim Sediment Quality Criteria, Threshold/Probable Effects Levels from Canada and the NOAA Effects Range (EVS Environment Consultants, 1996).

For human health guidelines, the tolerable daily intake values (TDI) were mostly from the United States Food and Drug Administration (http://vm.cfsan.fda.gov, cited in MPP-EAS, 1999b) and the rates of seafood consumption came from the Food and Nutrition Research Institute (FNRI, 1987). The list of criteria is presented as Appendix 4.

The choice of threshold values was based on what was available with the assumption that these values were suitable for Manila Bay. Most criteria and standards available have been generated in temperate regions so their relevance in a tropical area should be reviewed.

Average and worst-case (maximum) risk quotients from water-borne and sediment-borne substances and from consumption of contaminated seafood were calculated and used for comparative risk assessment. Comparative risk assessment provides a baywide perspective through the average RQs and a hotspot perspective through the worst-case RQs. It also shows the relative concern among the different chemical contaminants. This approach is conservative in that the worst-case conditions are presented. It also effectively screens out contaminants when the worst-case concentrations still do not indicate significant cause for concern, and this is the value of the initial risk assessment.

Results

The following are the results of the comparative risk assessment of both human health and ecological risks.

1. Human health risk arises from bathing in fecal coliform-contaminated waters (RQ_{max} = 4,500) and from consumption of seafood contaminated with fecal coliform (RQ_{max} = 2,667). Additional risks associated with high levels of some metals and pesticides in tissue also indicate that these are priority concerns.

2. Ecologically, in the water column, highest risk was associated with high phosphate levels. High RQs for DO, total suspended solids (TSS), and ammonia were also obtained. Intermediate risk was shown for nitrate, oil and grease and certain pesticides. Heavy metal levels showed low concern (RQ < 1) although very limited data were available for this parameter so this has to be verified using other data.

3. In the sediments, high risk was associated with copper and cadmium. Intermediate risk was shown for mercury, chromium, lead and certain pesticides. Polycyclic aromatic hydrocarbons (PAH), in general, showed acceptable risk except for an isolated value of dibenzo(a,h)anthracene, a carcinogenic PAH, that showed intermediate risk.

It is important to emphasize that the average RQs exceeded the value "1" for the following parameters: total and fecal coliform in the water column and tissue, phosphate in the water column and copper in sediments. This signals a general cause for concern, at least for all the stations where samples were taken. For DO, although the average RQ did not exceed one, low DO conditions over short periods may have considerable impact on fauna, particularly benthic animals. For the other parameters, the low average RQs indicate localized risks.

Data Gaps

The risk assessment, aside from highlighting areas of concern, also identified the following potentially important data gaps:

1. For water column, there were no available data on BOD/COD in the bay, PAHs and other organic chemicals and limited information on heavy metals, pesticides and oil and grease.

2. For sediments there were no available data on other organic chemicals, particularly organotins, and yet levels of shipping would suggest that these are potentially important contaminants derived from anti-fouling paints. And generally, there was a lack of appropriate criteria for pesticides and for TOC.

3. In terms of human health risks, there was a lack of available data for some pesticides and heavy metals in fish. There were no available data for pesticides, heavy metals and coliform in shellfish tissue as well as coliform in water from the western section of the bay. There was totally no available data on PAHs and TBT in tissue. There were also few TDIs for the pesticides, no TDIs for essential metals, and no criteria or standard for total coliforms in shellfish and fish tissue.

4. There was also inadequate data on phytoplankton in the water column, cyst counts in sediments and PSP levels in shellfish to conduct a risk assessment for toxic algal blooms.

5. There was lack of information necessary to be able to assess the likelihood of accidental oil spills from shipping and the consequent effects on the ecosystem. Rate of ship movements into and out of the bay, quantity and quality of cargo, experience of crew, age of vessel, and various other factors should be considered.

Uncertainties

1. MECs and PNECs

The risk quotients obtained and the conclusions drawn depend largely on the accuracy of the measured concentrations as well as the suitability of the threshold values that were used in calculating the risk quotients.

Considerable effort has been put to evaluating the reliability of the data used in the risk assessment although for some parameters for which there were very few data, the risk assessment was done using the available data.

For the threshold values, uncertainty may arise from the use of criteria or standards that were specified for temperate regions or other locations. The suitability of these values in the tropics, particularly in Manila Bay, still has to be verified.

In the assessment of risk to human health using tissue data, RQs for different age groups are obtained by dividing the measured contaminant levels in seafood tissue by the threshold value for different age groups. The threshold values are called levels of concern (LOCs) and are obtained by dividing the tolerable daily intake (TDI) for each age group by the consumption rate of the corresponding age group. In the initial risk assessment, only the local consumption rate was available so this was used to get the LOC for all age groups. If the consumption rate for the younger age bracket would be considerably less than that for the older age bracket, the use of average consumption rate for the former would generate a high LOC and, consequently, high RQ. This would tend to over-estimate the risk for the younger age group.

2. Limited data

The limited number of monitoring stations for all the parameters does not allow bay-wide generalizations to be made. It would be safe to apply the statements only to the areas where measurements were taken.

The limited data used for some parameters brings uncertainty to the results of the risk assessment. This is the case for heavy metals in water for which acceptable risks were shown and certain pesticides in the water column for which medium cause for concern was obtained.

3. Spatial and temporal variations

Worst-case conditions indicate potential hot spots but these were not identified. This would require analysis of spatial variability. Contaminant levels may also be affected seasonally so temporal variability should also be assessed.

The initial risk assessment has been based on average and worst-case conditions. More detailed uncertainty analyses would be needed to clarify some of the assessments. Consideration of spatial and temporal variability in the data would also enable more detailed and specific assessments to be made such as determination of relationships between predominant human activities and levels of contaminants. This would particularly be useful in the identification of contaminant sources and setting up of interventions.

At this point, it would be wise to reiterate that the results of the risk assessment are not always representative of the entire bay. For some of the parameters, the data represented only certain areas in the bay. Even for the parameters that were taken from stations spread across the bay, the large distances between stations do not allow absolute generalizations to be made. In using the results of the initial risk assessment, it would be more accurate to state clearly whether the statements apply to certain locations only or are being applied, with caution, to the whole bay. A more in-depth analysis of the data in the refined risk assessment may be able to address this.

Summary of Recommendations

1. *Risks to human health from coliform contamination*

Human health risk arises from fecal coliform contamination in the water column and in seafood tissue. The high bacterial load is attributed mainly to sewage generated from households and commercial, agricultural, institutional and industrial establishments that discharge directly to the bay or to the drainage and river systems which eventually enter the bay. To address this problem, several short-term and intermediate/long-term risk management recommendations are provided.

The following short-term recommendations are designed to confirm baseline information on the impact of sewage discharges into Manila Bay as well as to avoid human health problems.

a) Maintain and analyze morbidity and mortality data in communities surrounding Manila Bay.

b) Conduct routine monitoring of water and shellfish in bivalve-growing areas, fish and shellfish in market places, and waters in beaches or contact recreation areas.

c) Control food supply from contaminated bivalve-growing areas and regulate the use of contaminated beaches and bathing stations.

d) Conduct information campaigns on the results of monitoring and establish other measures to prevent possible human contact with contaminated waters and food.

e) Gather secondary data on coliform contamination or coliform loadings for all major tributaries.

f) Models should be used to identify and evaluate impacts as well as management options.

g) Perform benefit-cost analysis to identify appropriate interventions.

The following management recommendations are designed to address the root cause of sewage contamination in Manila Bay. These recommendations will require massive investment and take considerable time, but the initial risk assessment has determined these as priority areas for consideration as part of the risk management program.

a) Accelerate sewage collection and treatment programs in watershed areas

b) Eliminate direct discharges (i.e., no treatment) of domestic, industrial and agricultural waste, including septic or sludge disposal to Manila Bay and its tributaries

c) Implement control programs for indirect discharges, such as urban and agricultural run-off, to Manila Bay and its tributaries.

d) Provide safe potable water supply to households

Although the data used in the initial risk assessment only came from Metro Manila, the likelihood of similar situations (i.e., no centralized sewage collection) exists so these recommendations should be considered for the entire Manila Bay watershed.

2. *Risks to human health from heavy metals and pesticides*

Risks to human health are associated with high levels of some metals and pesticides in seafood tissue. The following are the recommendations for the refined risk assessment:

a) Identify morbidity and mortality statistics in areas surrounding Manila Bay and, if feasible, identify the extent to which human health has been affected by the levels of metals and pesticides in seafood tissue and identify vulnerable groups.

b) Conduct rapid appraisal of heavy metal and pesticide loadings to the bay

c) Use models to predict the fate of heavy metals and pesticides in the bay and estimate the levels in water, sediments and tissue.

d) For the computation of risk quotients, use local consumption rates and tolerable daily intake (TDI) data for different age groups. Consumption rates in coastal areas may also differ from consumption rates in in-land areas. Appropriate TDIs for essential metals should also be used.

As part of an overall environmental management of the bay, develop an integrated monitoring program to conduct routine monitoring of heavy metals and pesticides in seafood, particularly shellfish tissue.

In the sediments, high risk was associated with copper and cadmium. Intermediate risk was shown for mercury, chromium, lead, certain pesticides and PAH. Except for copper, elevated levels of the other abovementioned contaminants were localized.

There is no direct evidence that contaminants in the sediments pose risks to human health but because of human activities within the watersheds, it is prudent to include heavy metals, pesticides and PAHs in sediments as part of the refined risk assessment. The pathways to humans of heavy metals in sediments should also be determined.

3. Ecological risk from nutrients

Phosphate was determined to be a priority area of concern throughout the bay. On the other hand, ammonia was shown to be a localized high concern while nitrate was a localized intermediate concern.

Nutrients are required for primary productivity but elevated concentrations may cause eutrophication and may lead to phytoplankton blooms and, potentially, may trigger harmful algal blooms. These have implications on dissolved oxygen levels in the bay and, eventually, on the benthos and other sessile organisms.

To be able to determine the areas in the bay where high nutrient concentrations were obtained and where marked impacts may be more likely to occur, a detailed analysis of spatial variability is necessary. Analysis of temporal variability would also be needed to determine seasonal effects on the nutrient concentrations. A more detailed assessment of the linkage between elevated nutrient concentrations and phytoplankton blooms would also be a useful first step toward understanding the environmental and economic implications of nutrient discharges.

Spatial and time-series data of nutrients and dissolved oxygen at the sediment-water interface and in sediments will also be useful in assessing changes in the benthic community. Collaboration with research groups conducting such studies should be considered.

The possible sources of nutrients in Manila Bay are domestic, commercial and institutional waste and sewage, untreated or partially treated industrial effluents, particularly from the detergent and fertilizer industries, and agricultural discharge or run-off. All of these are contributing significant amount of nutrients to the bay but there is a need to determine the most significant sources to be able to prioritize interventions. This can be done by estimating or gathering information on loadings from the identified sources and by modeling.

4. DO/BOD/COD

The low levels of dissolved oxygen (DO) in the bay, especially in bottom waters, may have significant ecological consequences on the benthos and shellfisheries and, indirectly, on the organisms that feed on the benthos. Anoxic conditions also adversely affect aesthetics.

The main cause of reduced dissolved oxygen levels is the oxygen demand for the decomposition of organic materials in the bay. Organics come from continuous organic discharges from land-based human activities, tank-cleaning or operational discharges from ships and also from phytoplankton blooms.

BOD and COD are important water quality indices that reflect the amount of organic contaminants in the water. The problem is that there are no established standard methods for BOD and COD determination in seawater. The importance of these parameters in Manila Bay can be gathered from the high BOD and COD levels in the rivers draining to the bay and the low measured DO concentrations in the bay.

This demonstrates the need to estimate the oxygen demand in the bay using rapid appraisal. It also highlights the need to develop a model for organic loading and the potential impacts in the bay. The estimated organic load using the model can be verified using the results of the rapid appraisal and the BOD and COD measurements from the river systems. The predicted impacts in the bay can be verified using the dissolved oxygen measurements from monitoring activities.

To ascertain the degree of ecological impact of reduced DO levels in different areas in the bay and also to identify principal sources of organic load, it is recommended that a detailed analysis of spatial variability be performed.

A detailed analysis of DO measurements through time (temporal analysis) should also be performed to determine the duration of exposure of organisms to low DO and the likely acute or chronic effects.

Information on DO measurements during phytoplankton blooms should be gathered to determine the degree to which blooms affect DO levels, extent of area affected and duration of exposure of organisms to low DO levels.

It is also recommended that significant sources of the organic load be identified and the relative contribution of industries be determined.

5. *Sources and threshold value for TSS*

Suspended solids in the water column may reduce light penetration in the water and impair photosynthesis thereby affecting primary production and, consequently, the organisms at higher trophic levels. Suspended solids may cause smothering of corals and, potentially, adversely affect seagrasses. Suspended solids may also serve as adsorption surfaces for toxic contaminants and a transport route to the bottom sediments.

Suspended solids refer to organic and inorganic fine solid particles suspended in the seawater. It includes contributions from biological components like plankton and the excretion and remains of marine organisms. Other natural sources include eroded soil and rocks and lahar that are carried to the sea by runoffs. Suspended solids may also be derived from various land-use practices in the watersheds and along the coast like land reclamation projects, aquaculture and agricultural activities, and mining activities; from coastal erosion as a consequence of habitat destruction and sea level rise; from resuspension of bottom sediments as a consequence of dredging, trawling and natural mixing; and from industrial solid wastes, waste water, domestic discharges and waste dumping.

There is a need for a detailed analysis of spatial and temporal variability to determine the areas where elevated TSS concentrations were obtained and the variability in the concentrations with time.

There is uncertainty in the use of the interim standard of the Department of Environment of Malaysia for TSS (50 mg/l) as threshold level for TSS in Manila Bay. Other criteria do not specify values for TSS but instead indicate that the threshold should not be 30 mg/l greater than the annual average (DAO 34) or should not be 10% greater than the seasonal average (ASEAN) since there is natural variability in suspended solid concentrations in different locations. Information on background levels of TSS in the bay should be gathered or seasonal or annual averages should be calculated so that the TSS levels in the bay can also be assessed using other criteria.

In harmony with a hydrodynamic model of the bay, models showing the fate of suspended solids in the bay and the potential impacts on habitats and resources should be utilized.

Coastal erosion, which may be related to sea level rise, has implications on human activities especially along the coast. The relationship between coastal erosion and sea level rise and the impact on economic activities in the coastal area need further consideration as part of the refined risk assessment.

For environmental management, there is a need for a detailed analysis of the relative contributions of various sources of suspended solids. The contributions of various potential sources, especially those associated with human activities, should be evaluated. Environmental impact assessments (EIA) of reclamation and coastal development projects, in particular, should carefully assess the potential contributions of these activities to suspended solids in Manila Bay.

6. *Oil and grease*

The initial risk assessment indicated medium concern for oil and grease in the water column. This result seemed incompatible with the amounts of oil and grease that are visually observed at nearshore areas especially near the port. Oil and grease in offshore locations in the bay may not be elevated but measurements in near-shore areas especially near ports, refineries and industries may be higher and should be assessed.

The results of the risk assessment depended largely on the criteria value that was used as PNEC. Comparison of critical values for oil and grease from various sources showed differences by orders of magnitude. This would mean that the use of critical values from the lower end of the range could result to higher RQs than what were obtained in the initial risk assessment.

The complex mixture of organic compounds in oil and grease may have different adverse effects on marine life particularly shellfisheries and benthic organisms. It also has implications on oxygen demand for biological degradation and on aesthetics and recreation. Several medium and long-term recommendations are provided to address these concerns.

Oil and grease in the marine environment may come from various land-based sources, in particular, municipal wastes, urban run-off and petroleum refineries. It may also come from sea-based sources such as shipping activities.

It is recommended that:

a) more consideration and care be given to the choice of critical water concentrations for oil and grease in the refined risk assessment.

b) the major organic constituents of oil and grease in the bay be identified to enable the determination of ecotoxicological risks that these present to the ecosystem.

c) more information be gathered on the sensitivity of the resources and habitats in the bay to oil and grease, preferably to the toxic organic constituents, to determine the areas in the bay that are most ecologically at risk from large volume oil discharges.

d) a refined risk assessment of oil and grease in Manila Bay be made with special consideration of the relative importance of various land-based and sea-based sources. The risk assessment should take into account both controlled or operational discharges and uncontrolled or accidental discharges from industrial and shipping activities.

e) monitoring of oil and grease in bivalve-growing areas and near the port be done as part of the environmental monitoring component of the project.

f) additional information on accidental oil discharges be gathered. The frequency, location and volume of accidental oil spills as well as relevant information on the source of spill should be properly documented to determine areas where spills are most likely to occur and to determine other factors contributing to the occurrence of accidental spills. All these information will be valuable inputs to a model for prediction of the likelihood of accidental oil spills from shipping and the impact on the natural resources.

7. *Ecological risks from heavy metals*

For heavy metals in the water column, the initial risk assessment showed low risks associated with heavy metals in the water. The risk assessment was, however, performed using very limited data. A refined risk assessment for heavy metals in the water column is necessary. Data on heavy metals in the water column may, however, not be available. It is recommended that a rapid appraisal be conducted for heavy metals. Depending on the results of the rapid appraisal, heavy metals in the water column may be included in the environmental monitoring component of the project.

In the sediments, high risk was associated with copper and cadmium. Intermediate risk was shown for mercury, chromium and lead. Except for copper, elevated levels of the other abovementioned heavy metals were localized. These assessments, however, were made using data obtained from a limited number of stations in the bay.

The data used for sediments were obtained from a limited number of stations in the bay. It is recommended that data from other researches covering other areas in the bay be used to get an assessment that is more representative of the bay. It should be noted that data from various sources might not necessarily be comparable, so separate assessments for different data sets may be needed, but this will still be able to indicate trends in the spatial distribution of heavy metal contamination.

It is further recommended that detailed analysis of spatial variability be done to determine areas in the bay where elevated concentrations of heavy metals were found.

Heavy metals may come from both land and sea-based sources but the contributions from various land-based activities such as industrial and mining activities may be more significant. It is recommended that significant sources of heavy metals be identified. Models may be used to show the sources, distribution and fate of heavy metals in the bay.

It is recommended that the sediment criteria used as PNECs be evaluated. These criteria were proposed for Hong Kong and their suitability for use in Manila Bay needs to be reviewed. Grain size is an important factor that influences the concentration of heavy metals in sediments and Manila Bay sediments are fine-grained and muddy and may naturally have higher concentrations of metals than sediments from other locations. This can be done by determining the background concentrations of heavy metals in Manila Bay. These background concentrations may come from vertical sediment profiles or from offshore or reference sites, and may be available from government agencies or research institutions.

8. *Ecological risk from pesticides*

Localized intermediate risk was shown for certain pesticides in the water column and sediments. There are very few data for the water column while the data for the sediments were taken from a limited number of stations in the bay. There may not be much available data on pesticides in Manila Bay waters and sediments. It is recommended that a rapid appraisal of pesticides in Manila Bay be conducted. If the rapid appraisal shows significantly elevated concentrations of pesticides in the bay, it is recommended that pesticides in the water column and in sediments be included in the environmental monitoring component of the project.

It is recommended that detailed analysis of spatial variability be done to determine areas in the bay where elevated concentrations of pesticides would be obtained.

The major possible sources of pesticides in the bay are agricultural run-off and discharges from agro-based industries engaged in manufacturing pesticides. It is recommended that the relative contributions of the tributaries, especially Pampanga River where there are extensive agricultural activities, and other sources, be determined.

For other pesticides, RQs could not be computed due to lack of threshold values. It is recommended that a literature search be conducted for standards or criteria for pesticides especially since the RQs presented here indicate the need for a closer inspection of pesticide levels in Manila Bay.

9. *Ecological risks from PAHs*

The initial risk assessment of total PAH (TPAH) and carcinogenic PAHs from a study by Santiago (1997) indicated intermediate risk (RQ>1) for TPAH and acceptable risk (RQs < 1) for the carcinogenic PAHs. This study, however, showed that PAH levels in the eastern area, a more commercialized and urbanized area, were higher than the levels in the western side, indicating the anthropogenic source of PAHs. Another study (PRRP, 1999) also showed two stations in the bay where an RQ of 1.01 and 0.82 were obtained for the carcinogenic PAH dibenzo(a,h) anthracene.

PAH in water was not assessed due to lack of available data. There were data available on PAH in tissue but risk assessment could not be carried out because the values were all reported as less than the detection limit, which was even higher than the threshold value.

The study conducted by Santiago (1997) identified the PAHs in Manila Bay sediments as coming from petrogenic and pyrolytic sources. Petrogenic PAHs may come from oil discharges from ships, refineries and industries and pyrolytic PAHs are derived from combustion processes. Some PAHs may either be petrogenically or pyrolytically-derived. A more detailed analysis of the percentage composition of individual PAHs may indicate the more dominant source of PAHs in Manila Bay.

It is recommended that the levels of PAHs in the bay be verified. The availability of monitoring or research data on PAHs is not certain so it is recommended that PAHs in water, sediments and tissue be included in future monitoring activities in the bay.

10. Other organics

There were no available data on PCBs in water and sediments and TBT in all media. It is recommended that these data gaps be filled. The level of shipping activities in the bay indicates the need to look at the possible occurrence of organotins, especially since the negative effects of TBT on the reproductive processes of marine organisms, particularly mollusks, are well established. Measured concentrations of TBT may, however, not be available. Rapid assessment of TBT in Manila Bay can be done using estimates of leached TBT from ships and other users of anti-fouling paints. If the results of the rapid assessment warrants a more thorough evaluation of TBT levels in water, sediments and tissue, this parameter can be included in the environmental monitoring component of the project. Investigations on the occurrence of shell deformities and/or imposex (imposition of male characters on female gonad formation) in oysters should also be conducted.

11. Harmful algal blooms

There is also a need for a detailed understanding of the dynamics of toxic algal blooms and their interaction with environmental conditions. Predictive models are currently under development and it is recommended that a more detailed risk assessment be done in collaboration with the agencies and institutions involved in toxic algal bloom studies.

Other non-toxic phytoplankton blooms were not included in the initial risk assessment. Frequently, phytoplankton blooms indicate ecological problems in the bay such as eutrophication. These blooms may also affect dissolved oxygen levels with consequent effects on organisms in the bay and should be evaluated in the refined risk assessment.

Chlorophyll-a concentrations were also not discussed in the initial risk assessment. It is, however, an index of plankton biomass and could indicate when phytoplankton in the bay should be treated as a resource or an agent, and should therefore be included in the refined risk assessment.

Monitoring data on occurrences of phytoplankton blooms and levels of chlorophyll-a in Manila Bay may be available from various government agencies and research institutions.

12. Habitats

The results of the initial risk assessment have shown that mangroves and coral reefs are at risk in Manila Bay.

It is recommended that benefit-cost analysis of restoration of mangroves and protection of corals be conducted as part of an overall Manila Bay Strategic Environmental Management Plan (SEMP). This analysis should incorporate the social, economic and ecological benefits and costs. The question that needs to be addressed is "Are these habitats worth restoring considering other existing and potential economic activities in the bay?".

Economic benefit-cost analysis of all reclamation projects should also be required as part of government approval process.

In coming up with land and water use plans as part of the SEMP, an appropriate balance between the resources of the bay and economic activities should be targeted. Tradeoffs should be identified and evaluation of the value among the schemes, especially in terms of the resources and corresponding economic activities should be conducted.

13 Fisheries and shellfisheries

The decreasing trends in catch per unit effort (CPUE), stock density and demersal biomass, and the changes in catch composition, like the decrease in finfish population, indicate that there is a decline in Manila Bay fisheries. Overfishing and destructive fishing methods have been identified as the main causes for the decline and the fishing pressure exerted on the bay is indicated by the increase in number of fishers/km coastline and increase in number of boats/km coastline. Degradation of habitats like mangroves, seagrasses and coral reefs also contributed to the decline. These have led to reduced fish biodiversity, loss of economically important species, reduced fish yield, and consequent ecological, economic and social losses.

A general decline was reported in the combined production of oyster and mussel in Manila Bay from 1983 to 1988 and the windowpane oyster that used to be gathered in the eastern areas (Metro Manila) of the bay is disappearing. Overharvesting/overcollection had been identified as the main cause for the decline of the windowpane oyster in the bay, aggravated by pollution and destructive fishing methods. For the production decline from 1984 to 1988, low harvest due to low demand as a consequence of the red tide episodes may have been a significant factor although further evaluation is necessary to confirm this. It is also important to distinguish between impacts and causes of decline in shellfish from culture farms and from the wild.

The results of the initial risk assessment clearly indicate that fisheries and shellfisheries in Manila Bay are at risk and call attention to the strengthening of fisheries management in the bay. It is recommended that maximum sustainable yield, dynamic maximum efficiency yield, and depreciation values be determined. Maximum sustainable yield (MSY) refers to the maximum amount of resources that can be collected and still maintain the level of reproduction of these resources in the bay. This, however, may not be able to measure sufficiency over time or efficiency of harvesting of natural resources. Maximum efficiency yield (MEY) refers to the state where the marginal cost of effort is equal to the marginal benefits. Simultaneously, the utility and appropriateness of using the MSY for evaluation of fisheries exploitation in the bay should also be assessed, and other approaches, especially these that have been successfully applied in other locations, should also be considered. Dynamic MEY uses a discounting factor to take into account changes in values across time, i.e., the state where the present value of marginal cost equals the present value of marginal benefits. Depreciation indicates that the rate of change in the asset value of the stock is negative.

It is also recommended that interventions that will help in the recovery or restoration of the resources at risk be defined as part of the SEMP for Manila Bay.

14. Erosion and sedimentation

Erosion and sedimentation have been discussed in this report as contributors to suspended solids in the water column and as agents in the decline of some resources and habitats. These processes, however, which result from both natural and man-induced factors, can have more wide-ranging physical and biological as well as social and economic effects, and merit further assessment. Several studies have identified areas in Manila Bay where coastal erosion and sediment accretion have occurred.

Erosion and sediment accretion are on-going natural processes along all coasts. Natural factors that influence the coast such as waves, tides, currents and wind are beyond human control, but human activities that can add to the destruction of natural processes can be identified and eliminated or minimized. These activities include clearance of mangrove areas and coastal vegetation which decrease the stability of the shoreline, construction of harbors, jetties, seawalls and similar shoreline structures which change the normal wave patterns and can either accelerate erosion or interfere with long shore currents that carry sand from one place to another, and coastal developments and upland activities that affect sediment supply. These activities that lead to alteration of natural coastal processes could lead to undesirable effects on habitats and change community structure. Coastal erosion could also increase the risk of flooding and loss of infrastructure and shore-based facilities, and result in economic losses as well as increased cost for shoreline protection. Coastal accretion, on the other hand, creates new land for agriculture and aquaculture but the associated rapid siltation could have an effect on public and private investment. Siltation near ports, for instance, increases the need to invest in dredging facilities to improve access to ports.

In the refined risk assessment, areas in Manila Bay where shoreline changes have occurred should be assessed to identify possible causes of erosion or accretion and determine if these changes pose risks to the ecosystem, coastal communities and the economy. The contributions of coastal and watershed activities to shoreline change should also be considered in the development of the strategic environmental management plan for the bay.

15. In-depth risk characterization

The ecological component of the initial risk assessment has been directed to assessing effects of stressors to the ecosystem in general. An in-depth risk characterization would be needed to determine the effects of stressors to specific ecological entities. This would require PNECs that are specifically defined for particular targets (habitats or species). Some target-specific ecotoxicological data may now be available although more work will be required to produce this kind of data (MPP-EAS, 1999b).

Alternatively, conceptual models that indicate specific exposure pathways for different contaminants can be developed. These would demonstrate what stressors have primary or secondary effects on the targets, and also determine the likelihood of recovery. These would also indicate what other data would be needed for a more stressor/target-specific risk characterization.

16. Solid wastes

Solid wastes in the bay (and the surrounding river systems) pose risks to navigation, human health, ecological systems and aesthetics. The RQ approach used in the risk assessment has not been suitable for dealing with risks posed by solid wastes. It is recommended that alternative methods be used to assess these risks.

17. Coordinated monitoring programs

The initial risk assessment has shown the need for monitoring data for several parameters. It is recommended that systematic and coordinated environmental monitoring programs be developed. The environmental monitoring program should be aimed at systematic and cost-effective sampling activities and standardization of analytical procedures.

The initial risk assessment has also shown that retrospective risk assessment could not be carried out for some resources and habitats due to lack of information. It is recommended that systematic and coordinated ecological surveys be developed. The ecological surveys should be aimed at more precise inventories of natural resources and determination of appropriate assessment and measurement endpoints.

18. Collaboration

Partnerships between different government agencies, universities and scientific and technical research institutions, local government units, communities, non-governmental organizations, and the private sector would be vital to the development and sustainability of environmental management programs for the bay and should be promoted.

19. Access to data

A system to facilitate sharing of information and expertise should be developed.

20. Cost-benefit analysis

The development of management programs should involve the quantification of costs and benefits from alternative management strategies and from the activities that may be associated with environmental impacts. This is recommended for consideration in the risk management program and subsequent strategic environmental management plan and action plans.

21. Assumptions

All the assumptions and data sources used in every aspect of the risk assessment should be recorded and included as appendix in order to maintain the transparency of the process and enable checks and updates to be made on the assessments.

Background

The Regional Programme on Partnerships in Environmental Management for the Seas of East Asia (PEMSEA) has identified Manila Bay as one of the three subregional sea areas/pollution hot spots in the region to develop and implement a Strategic Environmental Management Plan in partnership with the national government and local stakeholders in the public and private sectors.

Risk assessment is one of the six component activities of the Manila Bay Environmental Management Project. Risk assessment is used in a wide range of professions and disciplines and is now increasingly being used in examining environmental problems. Environmental risk assessment (ERA) uses scientific and technical assessment of available information to determine the significance of risk posed by various factors emanating from human activities on human health and the ecosystem.

The gradual shift in environmental policy and regulation from hazard-based to risk-based approaches was partly due to the recognition that "zero discharge" objectives are unobtainable and that there are levels of contaminants in the environment that present "acceptable" risks (Fairman et al., 2001). Aiming for "zero discharge" levels or using the best available technology may not be cost-effective and could result in excessive economic burdens to society and adversely affect the provision of goods and services that contribute to human welfare. Risk assessment is a systematic and transparent process that provides comprehensive and logical information to environmental managers and decision-makers for identifying rational management options. Identifying areas of concern through the risk assessment also prevents the pitfalls of wasting effort and resources on minor concerns.

Various methodologies and techniques for ERA have been developed and different organizations are presently involved in further improving this management tool (ADB, 1990; UNEP-IE, 1995; UNEP-IETC, 1996; Fairman et al., 2001). The approach adopted by PEMSEA is based on the risk quotient (RQ) approach. It starts simply using worst-case and average scenarios and progresses if the results show the need for more refined assessment and more sophisticated ways of assessing and addressing the uncertainties associated with the RQ technique. The initial risk assessment of Manila Bay is a preliminary step to identify priority environmental concerns in the bay that will be the focus of a more comprehensive refined risk assessment.

The initial risk assessment of Manila Bay was initially conducted during the Regional Training Course on Environmental Risk Assessment held from July 17 to 28, 2000 at the PEMSEA Regional Program Office, Department of Environment and Natural Resources (DENR) Compound, Visayas Avenue, Quezon City, Philippines. The participants of the training course were from China, Thailand, Vietnam and the Philippines. The participants from the Philippines included experts and technical personnel from various government agencies and institutions who will be involved in the Manila Bay Environmental Management Project. Refinement of the initial draft was done following comments from various institutions.

Objectives

The objective of the study is to conduct an initial environmental risk assessment of Manila Bay using available information to determine the effects of factors derived from human activities on human and ecological targets in the bay.

Specifically, it aims to:

1. evaluate the impacts of various pollutants in the bay on human and ecological targets and identify the priority environmental concerns;
2. identify activities that contribute to pollution in the bay;
3. identify gaps and uncertainties that will need more effort in the refined risk assessment;
4. make recommendations for a refined risk assessment that is focused on the identified areas of concern;
5. identify agencies and institutions that can play significant roles in the refined risk assessment and in the long-term management of the bay; and
6. identify priority concerns to be addressed under risk management.

Sources of Information

Data for the retrospective assessment were mostly taken from the Resource and Ecological Assessment (REA) of Manila Bay (BFAR, 1995) that was completed in 1995 under the Fisheries Sector Program (FSP) of the Bureau of Fisheries and Aquatic Resources (BFAR). A majority of the information on resources and habitats, particularly on the decline of mangroves and corals, and on the status of seagrass, seaweeds, benthos, and fisheries were taken from this particular study. In addition, data for fisheries were taken from researches of the Bureau of Fisheries and Aquatic Resources conducted as early as 1947 (Blanco, 1947). Another major source of data on fisheries and socio-economic figures/features is the compilation of studies and reports from the Tambuyog Development Center. The reports prepared by the Department of Environment and Natural Resources (DENR) Region 3 and National Capital Region on the watershed of Manila Bay within their respective jurisdictions have also been useful.

The primary source of information for the prospective risk assessment was the Pasig River Rehabilitation Program Report (1999). This will be referred to in the text as PRRP (1999). Other materials that were used are also cited in the text. A detailed list of the sources of data for each parameter/resource is given in Appendix 2, which also includes descriptions of the data. Sampling stations are shown in Appendix 3 (a – e). The criteria used, which were also taken from various sources, are found in Appendix 4.

Most of the data used were presumed to be accurate and reliable, although preliminary screening was done for some data for which ranges of concentrations in different environmental conditions are known. Ideally, the reliability of data should be more systematically assessed based on the sampling design and laboratory techniques used to produce the data as well as the period when these were obtained. A more thorough assessment of data should be made in the refined risk assessment.

The choice of criteria was based on what were available with the assumption that these values were suitable for Manila Bay. Most criteria and standards available have been generated in temperate regions so their relevance in a tropical area should be reviewed.

Definition of Key Terms

The following are key terms used in risk assessment (a more comprehensive list of terms, as modified from U.S. EPA (1997), U.S. EPA (1998) and IUPAC (1993) is found in the Glossary):

Effects assessment - The component of a risk analysis concerned with quantifying the manner in which the frequency and intensity of effects increase with increasing exposure to substance.

Exposure assessment - The component of a risk analysis that estimates the emissions, pathways and rates of movement of a chemical in the environment, and its transformation or degradation, in order to estimate the concentrations/doses to which the system of interest may be exposed.

Hazard assessment - Comparison of the intrinsic ability of a substance to cause harm (i.e., to have adverse effects for humans or the environment) with its expected environmental concentration, often a comparison of PEC and PNEC. Sometimes referred to as risk assessment.

Hazard identification - Identification of the adverse effects that a substance has an inherent capacity to cause, or in certain cases, the assessment of a particular effect. It includes the identification of the target populations and conditions of exposure.

Risk - The probability of an adverse effect on humans or the environment resulting from a given exposure to a substance. It is usually expressed as the probability of an adverse effect occurring, e.g., the expected ratio between the number of individuals that would experience an adverse effect in a given time and the total number of individuals exposed to the risk factor.

Risk assessment - A process which entails some or all of the following elements: hazard identification, effects assessment, exposure assessment, and risk characterization. It is the identification and quantification of the risk resulting from a specific use of occurrence of a chemical including the determination of exposure/dose-response relationships and the identification of target populations. It may range from largely qualitative (for situations in which data are limited) to fully quantitative (when enough information is available so the probabilities can be calculated).

Risk characterization - The step in the risk assessment process where the results of the exposure assessment (e.g., PEC, daily intake) and the effects assessment (e.g., PNEC, NOAEL) are compared. If possible, an uncertainty analysis is carried out, which, if it results in a quantifiable overall uncertainty, produces an estimation of the risk.

Risk classification - The weighting of risks in order to decide whether risk reduction is required. It includes the study of risk perception and the balancing of perceived risks and perceived benefits

Description of Manila Bay

Manila Bay is a semi-enclosed estuary facing the South China Sea. The catchment area is bounded by the Sierra Madre mountain range to the east, the Caraballo mountains to the north, the Zambales mountains to the northwest and the Bataan mountains to the west. Manila Bay is connected to the South China Sea via a 16.7 km wide entrance. The surface area of the bay is 1,800 km^2. It consists of a gently sloping basin with the depth increasing at a rate of 1 m/km from the interior to the entrance. The mean depth of the bay is 17 m, and the volume is 31 km^3 (PRRP, 1999).

Manila Bay receives drainage from approximately 17,000 km^2 of watershed consisting of 26 catchment areas. The two main contributory areas are the Pasig and the Pampanga river basins. Most of the river systems in the province of Pampanga, Bulacan and Nueva Ecija drain into the Pampanga River (BFAR, 1995). Freshwater inflow has been estimated at approximately 25 km^3/year, but this figure is probably an overestimate. Seasonal and annual variations in discharges are pronounced with the largest input occurring in August and the lowest in April. The typical retention time for freshwater in the bay is between two weeks and one month, depending on the season (PRRP, 1999).

The population in the overall drainage area, as of 1995, is approximately 16 million (NSO, 1996). Manila Bay covers three regions: Region III, Region IV and the National Capital Region.

The tide is predominantly diurnal with an average tidal range of 1.2 m during spring tide and 0.4 m during neap tide. Seasonal wind systems (i.e., the monsoons) and diurnal breezes affect the current pattern especially in shallow water. The salinity of the water column is homogeneous in the dry season but increases from surface to bottom during the wet season. Median salinity at all depths is between approximately 30 and 35‰, a little less than the open ocean, with levels dropping, especially in surface waters during the rainy season. Seasonal and temporal variations in water temperature are slight and vary around 30°C (PRRP, 1999).

In terms of the local and national economies the major natural resources include fisheries, shellfisheries and aquaculture. Harvesting of mangroves is also of some importance. Other natural resources include coral reefs, seagrasses, seaweeds and algae. Important elements of the food chains within the bay include the phytoplankton as a source of primary production and benthos as a source of secondary production that is used as a source of food for fishes, which can be used directly for human consumption. It is also important to recognize that the physical habitats provided by the mangrove forests, coral reefs and seagrass beds are important refuges and nursery grounds for commercial and non-commercial fish and shellfish.

The primary economic activities in catchments and around the perimeter of the Bay are agriculture, forestry and fishery. There is also a variety of industrial activities that range from manufacturing to mining and quarrying. The major manufacturing industries include food and beverage, chemical, pharmaceutical, petrochemical and electronic industries. These are also the types of industries causing the most environmental concern. There is considerable reliance on a fishing trade that involves both local and distant fishing grounds with the Port of Navotas being the focus of activity and representing one of the largest fishing ports within the Philippines. There is also a shipping industry involving transport of passengers as well as oil and containers of various kinds. There are reclamation and construction activities that can have effects on the habitats and also contribute to suspended materials in the bay. Agricultural and forestry activities, especially in the catchment areas of the rivers, can also contribute to pollution loadings from agrochemicals, agricultural wastes and soil erosion.

Domestic activities lead to the production of solid wastes and sewage, which enter the bay from river catchments and directly from around the perimeter. Pollution brought about by an inadequate solid waste program continues to be a serious environmental problem. For example, between 5,000 to 6,000 tons of solid waste are generated daily in Metro Manila with less than this capacity being handled by the solid waste management facilities. A considerable amount of solid waste is therefore able to enter the Bay directly from the perimeter, indirectly from catchments via the river systems, or directly from shipping.

At present, less than 7% of the population in eleven major cities and municipalities in Metro Manila, with estimated combined population of about 8.4 million people based on the 1995 census (NSO, 1996), has access to adequate sewerage systems so that about 8 million people in these areas are contributing domestic liquid waste pollution either directly to the Bay or via the river systems (PRRP, 1998). Moreover, the existing sewerage system directly leads to an outfall into the bay, with sewage being discharged with no treatment. In consequence, the BOD loading of rivers is very considerable. It is clear that the discharges of untreated domestic sewage into river systems and along the shoreline have contributed significantly to the deteriorating quality of the Bay in general.

The Risk Assessment Approach

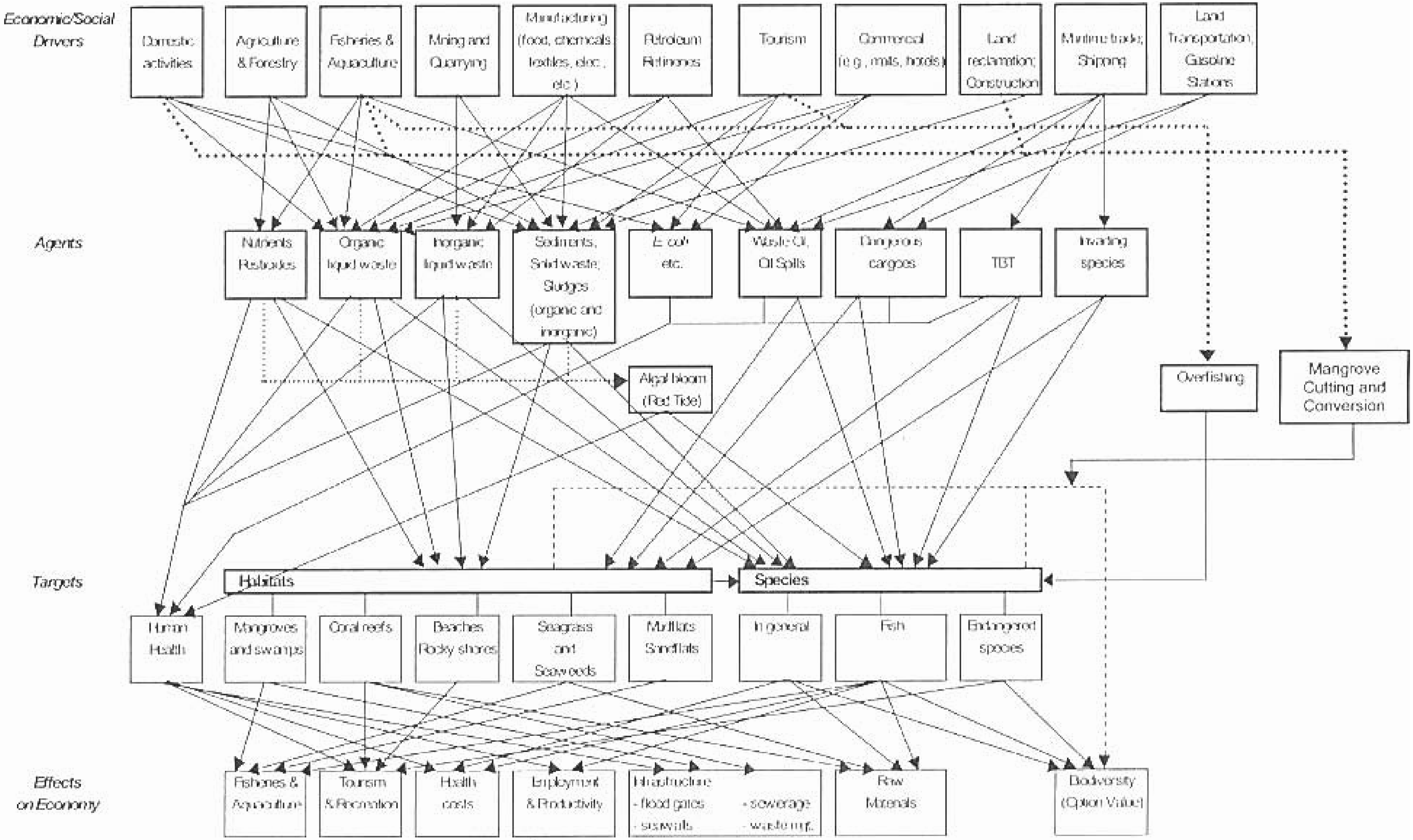
Risk is the probability of an adverse effect on humans or the environment resulting from a given exposure to a substance. It can be carried out as a retrospective risk assessment or a prospective risk assessment. For the retrospective risk assessment, the fundamental question concerns the extent to which conditions are likely to have caused adverse effects observed in specific targets. Prospective risk assessment considers the extent to which current conditions, and/or those likely to pertain to the future due to new developments, would likely cause harm. Both can be used as a basis for environmental management and imply the desire to control activities and conditions to levels that do not cause harm and which are likely to be nonzero. In the Manila Bay Environmental Management Project, a combination of retrospective and prospective approaches is used. A retrospective approach is applied to explain observed deterioration in ecological targets and/or the occurrence of human health problems in terms of likely levels of exposure and their causes. A prospective approach is applied to consider and compare the likely adverse effects emanating from observed environmental concentrations of chemicals. The approaches converge to indicate the relative importance of different adverse effects and their causes. This should lead to appropriate, cost-effective management programs.

The fundamental features of both retrospective and prospective risk assessment are that they identify problems and their causes based on systematic and transparent principles that can be justified in public and can be revisited as more information and understanding become available. The key concept for risk assessment is the comparison between environmental conditions (e.g., environmental concentrations of chemicals) and threshold values likely to cause adverse effects in the targets under consideration. In prospective risk assessment, this is made explicit as a risk quotient (RQ), that is the ratio of an environmental concentration (either predicted (PEC) or measured (MEC)) with a predicted no-effect concentration (PNEC) for the target of concern (RQ=P(M)EC/PNEC). An RQ < 1 indicates a low, and thus acceptable risk, and an RQ ≥ 1 indicates a level of concern and possibly the implementation of appropriate management programs.

The basic principles and techniques for both retrospective and prospective risk assessment are described in Environmental Risk Assessment Manual: A Practical Guide for Tropical Ecosystems, Technical Report 21, GEF/UNDP/IMO Regional Programme for the Prevention and Management of Marine Pollution Prevention in the East Asian Seas, Quezon City, Philippines (MPP-EAS, 1999a).

The simplified risk pathways in Manila Bay (Figure 1) brings together the possible sources of hazards to human health and the environment and shows the possible effects on the economy. It also indicates the relationships between the sources of hazards and various economic and social drivers. This qualitative illustration draws attention to specific activities that may cause problems to human health and the environment and aids in the prioritization of concerns for risk assessment and, ultimately, risk management, especially when human health and environmental protection will need to be weighed against economic realities.

Figure 1. Simplified risk pathways for Manila Bay.



Retrospective Risk Assessment

INTRODUCTION

Retrospective risk assessment is an evaluation of the causal linkages between observed ecological effects and stressor(s) in the environment. It addresses risks from actions that began in the past and can therefore be assessed based on measurements of the state of the environment (Suter, 1998). It attempts to answer the question: "What evidence is there for harm being done to targets in the bay?" (MPP–EAS, 1999b). In retrospective studies, it is important to identify significant effects (targets and endpoints) and ascribe causation. The approach involves making inferences about the causes of observed effects (Suter, 1998) – and this often requires temporal and spatial series of data for comparative purposes. Comparison facilitates the ascribing of risks to a particular source.

The retrospective approach employed for Manila Bay was of the "effects-driven assessment" type that addresses apparent ecological effects that have uncertain magnitudes and causes (Suter, 1998). Under this perspective, risk is viewed as the likelihood that current impacts are occurring and that demonstrating these existing impacts confirms that a risk exists. It is important to note that impacts have primary or secondary effects – as these may cause direct or indirect changes in identified targets. These impacts range from those occurring inland and near the coast to those occurring in the bay itself as consequences of developments and ecosystem exploitation.

METHODOLOGY

A considerable volume of materials on Manila Bay, from various studies, reports, and projects, were reviewed and relevant data on identified targets (habitats and resources) in the bay were put together for the retrospective risk assessment. Steps prescribed in the Environmental Risk Assessment Manual (MPP-EAS, 1999a) were, likewise, applied.

Problem Formulation

The problem formulation phase involved defining the target and the way it is impaired by recognizing that an undesirable effect on an ecological system or human population has already occurred, identifying suspected (or known) agents, and considering the links between the agents and the adverse effects on the targets with an aim to eventually manage these agents in order to reduce harm.

It is also important to determine the assessment and measurement endpoints in the targets. Assessment endpoints are features related to the continued existence and functioning of the identified targets (e.g., production, density changes and mortality), which may not be easy or would take much time to measure. So measurement endpoints, which are features related to the assessment endpoints but are easier to measure are used instead such as biomass (for production), abundance (for density changes) and LC_{50} or biomarkers (for mortality).

To elaborate on the interrelatedness of agents and targets, a simplified risk pathway (Figure 1) was used.

The suspected agents for the different resources and habitats include: a) overfishing (overcollection/overharvesting), b) destructive and illegal fishing, c) physical disturbance, d) physical removal/clearance, e) sedimentation, f) insect infestation, g) dissolved oxygen, h) biochemical oxygen demand (BOD), i) chemical oxygen demand (COD), j) nutrients, k) coliform, l) toxic algae, m) heavy metals, n) pesticides, o) total suspended solids (TSS), p) total organic carbon (TOC), q) oil and grease, r) polyaromatic hydrocarbons (PAHs), s) polychlorinated biphenyls (PCBs) and other organics, and t) oil spills.

The identified targets for resources include: a) fisheries, b) shellfisheries, c) seaweeds, d) benthos, and e) phytoplankton, while the identified targets for habitats were the following: a) mangroves, b) coral reefs, c) seagrass beds d) soft-bottoms, e) mudflats, f) sandflats and beaches, and g) rocky shores.

Retrospective Risk Assessment

Under the retrospective risk assessment phase, a set of questions, answerable by yes (Y), no (N), unlikely (unl), or unknown (unk), was formulated in order to establish evidences of decline, and the causes and consequences of the decline. The following questions were adapted from the Environmental Risk Assessment Manual (MPP-EAS, 1999a).

1) Is the target exposed to any of the agents?

2) Was there any loss/es that occurred following exposure? Was there any loss/es correlated through space?

3) Does the exposure concentration exceed the threshold where adverse effect starts to happen?

4) Do the results from controlled exposure in field experiments lead to the same effect? Will removal of the agent lead to amelioration?

5) Is there specific evidence in the target as a result of exposure to the agent?

6) Does it make sense (logically and scientifically)?

The different categories of likelihood of harm are as follows:

1) Likely (l) - based on knowledge of exposure to the agent and either established effect concentrations (i.e., criteria used in prospective analyses) or other evidence (such as knowledge about intentional harvesting, field observations (e.g. of infestation), the agent is considered to be a likely cause of decline in the resource or habitat;

2) Possibly (p) - based on available information about exposure and effect levels, this agent cannot be excluded as a cause of decline in the resource or habitat;

3) Unlikely (unl) - based on available information about exposure and effect levels, this agent is unlikely to have caused decline in the resource or habitat. However, agents in this category may have indirect effects on the resource. For example, nutrients, themselves, would not have a negative effect on benthos (defined here as unlikely), but by enhancing primary productivity (algal blooms), increased nutrients could lead to lowered DO, which is likely to have a negative impact on benthos; and

4) Unknown (unk) - there is not enough information available on exposure and/or effect levels to assess whether agents in this category have led to decline in the resource.

In order to facilitate the assessment, all the abovementioned questions were tabulated in a matrix where each of the targets was subjected to the series of questions. The answers to the questions were based on available information on the targets and agents. The matrices are termed here as "decision tables". Using these tables, agents that were likely to have caused adverse effects have been systematically screened.

Upon screening, summaries of likelihood some identified agents causing decline in resources and habitats (see Appendix 1) were prepared and were made part of the basis for the results of the retrospective risk assessment. It is important to note that the summaries of likelihood were established on the basis of the retrospective analyses (decision tables) and on the prospective risk assessments for different agents summarized in the Comparative Risk Assessment section.

After establishing evidences of decline in the resources and habitats, the ecological, economic, and social consequences of decline were evaluated.

RESOURCES

Fisheries

Evidence for Decline

The following are based on data generated by the Resource and Ecological Assessment of Manila Bay (BFAR, 1995), the compilation of studies by Tambuyog Development Center (1990), and the Socioeconomic and Investment Opportunities Study in Manila Bay (FSP-DA, 1992). Table 1 summarizes the retrospective analysis for fisheries in Manila Bay.

Table 1. Retrospective Analysis for Fisheries in Manila Bay.

Resource Type	Areal Extent	Results		Impact
		Change/s Observed	Identified Agent/s	
Fisheries	Large	Quantity: • CPUE (kg/hr) decline: 46 to 13.8 (1947-1959) 94.1 to 27.9 (1970-1983) 14 to 10 (1986-1993) • Increase in fishers/km coastline: 70 to 253 (1987-1993) • Increase in boat/km coastline: 74 (1980), 95 (1991), 105 (1993) • Demersal biomass estimates: 4.61 mt/km^2 or 8,290 tons to 0.47 mt/km^2 or 840 tons (1947-1993) Quality: • Decreased finfish population – increased invertebrate population of the demersal fisheries (squids, "alamang", and other crustaceans) • Disappearance/near absence of some species: (e.g., *Saurida tumbil*)	Most likely • Overfishing – increase in the number of fishers and use of gears with increased efficiency for catching (marked increase in trawls and capacity) Likely: • Dynamite fishing • Low DO • Destruction of habitats Possibly: • Heavy Metals • TSS • Pesticides Oil and Grease	• Loss of economically important species • Reduced yield (fishery production) • Species succession • Use of gears with increased efficiency to catch remaining/ existing dominant species

Sources: BFAR, 1995, Tambuyog Development Center, 1990 and FSP-DA, 1992.

Catch per unit of effort (CPUE) is the number or weight of fish caught by a unit of fishing effort, e.g., weight in kilograms (kg)/hour of searching. It is often used as a measure of fish abundance. The trend in CPUE clearly indicates that there is a decline in the Manila Bay fisheries. Estimates made in 1993 show that should the trend continue, present CPUE would be lower than 10 kg/hr. There was a reduction from 46 kg/hr to 13.8 kg/hr from 1947 to 1959. A similar trend was observed in 1970 to 1983 when the CPUE dropped from 94.1 kg/hr to 27.9 kg/hr. In 1986 to 1993, the CPUE again dropped from 14 kg/hr to 10 kg/hr. The seeming inconsistency, particularly of the 1947-1959 period with those of the recent estimates, is mainly due to design differences in fishing gears, which had lower catching efficiency based on the technology available during the period.

Based on the BFAR study (1995), demersal biomass estimates were made utilizing the swept area method for both the 1947 and 1992-1993 sets of observations. Biomass is the total quantity (at any given time) of living organisms of one or more species per unit of space (species biomass), or of all the species in a biotic community (community biomass). The method used, in reference to demersal trawls, makes use of the swept-area, which is the area of the sea floor over which the net is dragged during its operation. The swept-area is estimated by multiplying the width of the net mouth by the distance the net is dragged. From data on the densities of fish caught in a unit area swept, an estimate of the biomass in that part of the sea can be obtained. For the bay (approximately having a surface area of 1,800 square kilometers), it was established in 1947 that there was supposed to be a stock density of 4.61 metric tons per square kilometer (mt/km^2) or about 8,290 mt of demersal biomass, while in 1993 there was only an estimated 0.47 mt/km^2 or an equivalent of 840 mt.

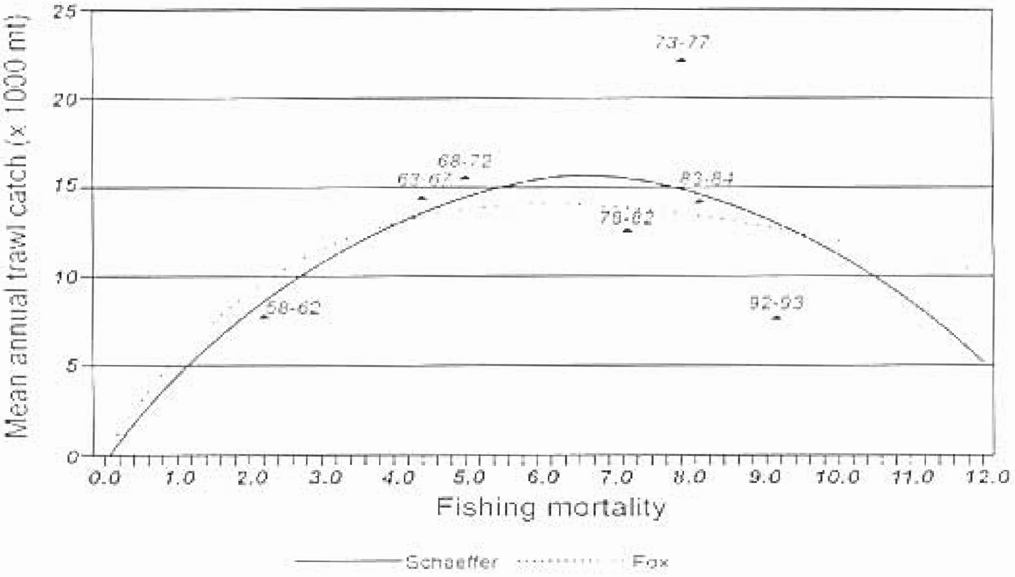
With the application of the Schaeffer and Fox surplus production models on the set of trawl fisheries data, the maximum sustainable yield (MSY) for demersal catch was computed (BFAR, 1995). Surplus production models involve the use of "surplus production", which is the production of new weight by a fishable stock, plus recruits added to it, less what is removed by natural mortality. This is usually estimated as the catch in a given year plus the increase in stock size (or less the decrease). The results of both models (summarized in Figure 2) show that the maximum sustainable yield for demersal catch is around 15,000 mt/annum with a fishing mortality of about 6.3. The study suggests that this level may have been reached as early as 1970, so that the rate of exploitation in 1993 was way above the maximum effort which can produce the maximum yield.

Similarly, there was also a decline in terms of the quality of fish yield in the bay, particularly in the composition of species caught. The population of finfish decreased which led to a corresponding increase in the invertebrate population of the demersal species. Major changes noted in catch composition include "increase in the abundance of squid, shrimp, and small pelagic species, such as herrings and anchovies, the disappearance of turbots and lactarids, and the decline of usually large commercial species like snappers, sea catfish, and mackerels" (BFAR, 1995).

One particular species, the *kalaso* or Greater/Common Lizard Fish (*Saurida tumbil*), used to be caught in large numbers in the past but are now very few and, if ever caught, are usually small in size.

Due to excessive fishing and the eventual decline in mature fish population, some species were unable to complete their life cycle, from juvenile stage to maturity, with more being caught still at the juvenile stage. Thus, there was an observed small and/or reduced size (length) of fish caught. Fishing pressure was also exerted on small demersal and pelagic species, and has further led to their disappearance or a reduction in their population. It is suspected that this may have likely disrupted the natural succession of fish species in the bay (BFAR, 1995).

Figure 2. Combined results of the Schaeffer and Fox surplus production models.



Source: Resource and Ecological Assessment of Manila Bay (BFAR, 1995).

Attributed Causes

Overfishing was identified as the most likely cause for the decline in fish population and catch – both in terms of species composition and size. This can be correlated with the corresponding increase in the number of fishers per kilometer of the coastline, from 70 to 253 in 1987 up to 1993. Accompanying the increase in fishers is an increase in the number of boats (municipal) per kilometer of the coastline, estimated by dividing the reported number of boats by the approximate length of the Manila Bay coastline (190 km). The number of boats increased from 74 units/km in 1980 (NCSO Census on Fisheries, 1980 cited in Tambuyog, 1990) to 95 units/km in 1991 (FSP-DA, 1992)) and to 105 units/km in 1992-1993 (BFAR, 1995), which indicates the intensity of fishing effort in the bay.

In addition, destructive and illegal fishing methods, the destruction of habitats, and pollution (e.g., increased organic load and consequent low DO) were also considered to have adversely affected fishery productivity in the bay. Fine meshed nets, trawls, and motorized pushnets, commonly used in the bay, coupled with the availability of and easy access to explosives by fisherfolks have led to such destructive and illegal practices.

The effects of other pollutants such as heavy metals, pesticides, oil and grease, and high total suspended solids (TSS) on the fisheries could not be totally excluded and, in varying levels and actions, may have contributed to the observed decline.

Consequences

Overfishing has led to reduced fish biodiversity (e.g. decrease in the finfish population and an increase in invertebrate population of the demersal fishes), loss of economically important species, reduced fish yield, and the consequent economic and social losses.

The use of simple fishing gears is no longer effective. Fisherfolks, particularly those who depend on subsistence fishing are, therefore, economically and socially disadvantaged.

Shellfisheries

Evidence for Decline

The main shellfish species cultured in the bay are *Perna viridis*, locally known as *tahong*, and *Crassostrea iredale*, the rock oyster, locally known as *talaba*.

A profile of economic activities in Manila Bay (part of the compilation of studies on Manila Bay prepared by the Tambuyog Development Center) shows the trends of shellfish production from 1983 to 1988 as cited from the Bureau of Agricultural Statistics (BAS) 1988 Fishery Statistics. The data showed increase in production from 1983 to 1984 for both oysters and mussels, followed by decreasing trends from 1984 to 1988. The combined production of oysters and mussels shows that from a peak of 17,292 mt in 1984, production went down to 10,388 mt in 1988. In 1987, particularly, oyster production decreased sharply by 4,173 mt while mussel production decreased by 2,174 mt.

Table 2. Retrospective Analysis for Shellfisheries in Manila Bay.

Resource Type	Areal Extent	Results		Impact
		Change/s Observed	Identified Agent/s	
Shell fisheries	Small	Quantity: • oyster: steady decline from 6,292 mt in 1984 to 1,730 mt in 1988 • mussel: decline from 11,018 mt in 1984 to 8,658 mt in 1988 • disappearing windowpane oyster (from 450 to 460 seedlings/m^2 in Parañaque in 1947) Quality: Contamination of shellfish tissue with coliform, heavy metals and pesticides	Most Likely: • Overharvesting / overcollection Likely: • Pollution. Dumping of domestic and industrial sewage/ heavy metals, TSS, pesticides, PAH, oil and grease • Destruction of habitats (through reclamation/ conversion and destructive fishing methods • Phytoplankton blooms (causing anoxic conditions)	• Loss of economically important species • Reduced yield (production)

Sources: BFAR, 1995, UNEP/EMB-DENR, 1991, Tambuyog Development Center, 1990, and Blanco, 1947.

In addition, the windowpane oyster that used to be gathered and actually cultured in the eastern areas (Metro Manila) of Manila Bay is disappearing. Based on the report of the Proposed River Rehabilitation Program for the Manila Bay Region (UNEP/EMB-DENR, 1991), the windowpane oyster is disappearing as a result of overexplotation and pollution.

A 1947 publication of the Philippine Journal of Fisheries (Blanco, 1947) reported that the windowpane oyster, *Placuna placenta*, locally known in the Philippines as *kapis*, used to be extensively cultivated in Bacoor, Cavite. The kapis seedlings were sourced from what was then Parañaque, Rizal (now Parañaque, Metro Manila) where 80 to 100 seedlings/ft of the sandy, exposed wet beach and from 450 to 460 seedlings/m^2 in the shallow lagoons were found. Seedlings were also gathered at Navotas, Rizal (now Navotas, Metro Manila) where a seedling collector usually was able to gather from 5,000 to 10,4000 pieces from early morning to sunset.

In terms of the quality of the shellfish resources, specifically for human consumption, the results of the prospective risk assessment indicated high concern for the levels of fecal coliform, heavy metals and certain pesticides in shellfish tissue.

The retrospective analysis for shellfisheries in Manila Bay is found in Table 2.

Attributed Causes

For the windowpane oyster, the main factor for the decline was the enormous demand for kapis shells, especially the thin and transparent shells of the young oysters. Other factors that accounted for the decline include pollution, suffocation due to deposition of mud and sand on the natural beds and absence of food for its proper growth.

The shellfish production data presented here were obtained after the first red tide episode in the bay (1983) and on subsequent years (1984 – 1988) which were also marked with several red tide occurrences. This may be one of the reasons for the sharp decrease in production in 1987. Increased public awareness about the human health impacts of the red tide occurrences may have significantly lowered the market demand for shellfish from the bay or shifted the demand to other areas, although the effect of pollution cannot be disregarded. The prospective risk assessment has shown that the levels of nutrients, suspended solids, heavy metals, pesticides and oil and grease in the bay present considerable risks to the ecosystem. Low dissolved oxygen levels, arising from excessive organic loading, can have adverse impacts on shellfisheries.

Other factors that may have contributed to the decline include destruction of habitats through reclamation and conversion of nearshore areas that were formerly utilized as shellfishery grounds, and, to an extent, destructive fishing methods.

Another contaminant that is known to adversely affect the reproductive processes of some organisms, particularly mollusks, is tributyltin (TBT), a substance used in anti-fouling paints for ships (Swennen, 1996, cited in MPP-EAS, 1999b). There were no available data on TBT and its effects on organisms in the bay, but it is likely to occur in the bay, and should be taken into account.

Another threat to shellfisheries, both cultivated and found in the wild, are the phytoplankton blooms which include the red tide phenomenon. In 1987 at the Bacoor Bay, there were documented reports of cultured mussels and oysters that perished due to reduced DO levels during the height of the red tide bloom.

Consequences

All of the agents mentioned have severely affected the shellfisheries of the bay to an extent where economically important species are disappearing, as in the case of the windowpane oyster, and the yield of the other remaining species are continuously declining.

A spin-off effect of the red tide phenomenon is the lowered demand for shellfish as the public has become better informed of the fatal effects of paralytic shellfish poisoning (PSP). Economically, shellfish culture and farming industries were adversely affected.

Seaweeds

Evidence of Decline

With the lack of available comparative historical information, it was not possible to determine a decline in seaweeds in the bay. Based on the Resource and Ecological Assessment of Manila Bay (BFAR, 1995), the available information only pertains to recent distribution, being widespread, with 52 species found belonging to 33 genera, 21 families, and 15 orders, with Rhodephyta, Phaeophyta, and Cholorophyta as the most common orders. In addition, *Sargassum* and *Gracilaria* were found to be the dominant species. The retrospective analysis of seaweeds is presented in Table 3.

From eight sampling stations within the bay, it was established in 1993 that seaweeds had low mean abundance, 25 to 31 individuals per 0.5 square meter (ind/0.5 m^2) in Mariveles and Orion in Bataan, in Malolos, Bulacan, and Corregidor Island. There were noted intermediate mean abundance (35 to 47 ind/0.5 m^2) in Parañaque, Metro Manila, and in Bacoor and Tanza, Cavite; and high mean abundance, 61 ind/0.5 m^2, in Ternate, Cavite. Diversity indices are distributed as follows: high (greater than 2.4) in Mariveles, Bataan and in Ternate, Cavite and Corregidor Island, intermediate (1.6 to 1.9) in Parañaque, Metro Manila and Bacoor, Cavite, and low (0.3 to 1.0) in Orion, Bataan and Malolos, Bulacan.

Attributed Causes

Potential agents known to adversely affect seaweeds include sedimentation, utilization, and pollution.

Consequences

A decline in seaweed abundance and diversity may lead to loss of economically important species as well as the loss of its ecological functions.

Table 3. Retrospective Analysis for Seaweeds in Manila Bay.

Resource Type	Areal Extent	Results		Impact
		Change/s Observed	Identified Agent/s	
Seaweeds	Small	Information provided in available literature: • 52 species • most common orders: Rhodophyta, Phaeophyta, and Chlorophyta • *Sargassum* and *Gracilaria* as dominant species	• Sedimentation • Utilization • Pollution: Oil and Grease Oil Spills Heavy Metals Pesticides PAH	• Loss of economically important species • Loss of ecological functions - food for marine animals - source of nutrients

Source: BFAR, 1995.

Phytoplankton

Evidence of Decline

There are no available data to suggest the decline of phytoplankton in Manila Bay. An inventory-assessment made as part of the Resource and Ecological Assessment of Manila Bay (BFAR, 1995) showed that, for the sampling stations occupied, there were sixty-three genera of six algal divisions that were identified. Baccilariophyta dominated the species group throughout the year. Highest phytoplankton density and diversity was noted from January to March 1993, accounting for 57 of the total 63 genera known to be present in the bay but which decreased abruptly to 35 during the dry season (April 1993). Table 4 summarizes the findings of the retrospective analysis for phytoplankton.

Based on other available and related data (PRRP, 1999), chlorophyll-a measurements were noted to be increasing, indicating that phytoplankton in the bay also increased during the time of observation (1996-1998).

Table 4. Retrospective Analysis for Phytoplankton in Manila Bay.

Resource Type	Areal Extent	Findings
		Change/s Observed
Phytoplankton	Large	Information from available relevant literature: • genera present – 63 • dominant group: Baccilariophyta (among stations) • period of highest diversity and density is: Jan-Mar 1993, while period of lowest diversity and density is April 1993)

Source: BFAR, 1995.

Although there was no observed decline in phytoplankton, attention should also be given to the potential effects of suspended solids and other pollutants in the water column to primary productivity. High amounts of suspended solids may reduce or even inhibit primary productivity. The reduction or inhibition of primary productivity will have a chain effect on succeeding trophic levels. The ecological importance of this resource makes it as valuable as the other resources dependent for it in the food chain.

HABITAT TYPES

Mangroves

Evidence for decline

A majority of the data utilized for the assessment of mangroves was taken from the Resource and Ecological Assessment of Manila Bay (BFAR, 1995). The study mentioned estimates of around 54,000 hectares of mangrove forests in Manila Bay at the turn of the century (1890). Further estimates showed that after 100 years (1990) there were only 2,000 hectares left, but which were further reduced to 794.37 hectares based on computations in 1995. The following provinces have had the most significant mangrove forest losses: Pampanga, Bataan, Bulacan and the town of Navotas in Metro Manila. The retrospective analysis of mangroves in Manila Bay is shown in Table 5.

Table 5. Retrospective Analysis for Mangroves in Manila Bay.

Habitat Type	Areal Extent	Results		Impact
		Change/s Observed	Identified Agent/s	
Mangroves	Small	Quantity: Very large decline - baywide • from an estimated 54,000 hectares in 1890 to 2,000 hectares in 1990; and from 2,000 hectares in 1990 to 794.37 hectares in 1995 Quality: No data	Most Likely: • Physical removal for the ff. activities: - Conversion (i.e. for aquaculture and salt beds) - Land reclamation and other development activities - Cutting for fuelwood and housing) • Sedimentation from upland activities Possibly: • Pollution: Oil Spills, pesticides • Pest infestation (localized) • Lahar suffocation (localized)	• Degradation or loss of habitat and nursery grounds • Loss of natural protection • Reduced biodiversity • Coastal erosion and siltation • Loss of carbon storage • Reduced detritus • Secondary adverse impacts to adjacent coral reefs, sea grass beds, and other habitats

Source: BFAR, 1995.

Attributed causes

The major cause of the decrease of mangrove is clearance for conversion into aquaculture and salt beds, land reclamation for human settlement, industrial development and other development activities. Physical removal for fuel wood was also one cause of decline. Wood from mangrove stands is known as excellent firewood for ovens used in bakeries.

Other factors attributed to cause the decline in mangrove forests include pollution, i.e., from oil spills, chemicals, and floating solid debris/wastes that clog the root system of mangrove stands, and sedimentation as a result of upland/upstream activities. Pest infestation may have contributed to the decline although on a more localized level, as occurrence was observed only in the mangrove stands found within the NCR area. The increased susceptibility of the mangroves to pests may be a manifestation of an ecosystem under stress, as a consequence of pollution and physical disturbance. Lahar suffocation has also contributed to the decline in mangrove forests in Pampanga.

Consequences

Destruction of mangrove forests in Manila Bay have led to the loss of ecological functions such as breeding, spawning and nursery grounds, natural protection from wave action, protection from coastal erosion and siltation, and storage for carbon. It also has secondary adverse impacts to adjacent coral reefs, sea grass beds, and other habitats. Consequently, productivity of marine animals, particularly the commercially-important species, is adversely affected. The reduced fish productivity ultimately affects the economy and the people dependent on fishing for livelihood, especially the small-scale fishers. The loss of natural coastal protection also affects the safety of coastal communities from floods and typhoons.

Coral Reefs

Evidence for Decline

There has been a decline in coral reefs in Manila Bay, but there is no definite figure or estimate for the said decline. A resource and ecological assessment conducted in 1992 – 1993 (BFAR, 1995) reported that a large section of the reef at the entrance of the bay, particularly the thick growth of *Acropora sp.* had already been damaged. Other information from the same report were limited to percentage of coral cover, species diversity, structure, location, and distribution. Percentage of live cover is as follows: 20 in Mariveles, 40 to 80 in Cavite (Limbones Cove), and 20 in Corregidor Island. There were about 14 families of hard corals, one family for soft coral composed of 38 genera and 53 species that were categorized as ecologically poor in condition. Structure-wise, those found were of the fringing type composed of generally encrusting forms and massive in habit with no solid stands, and are mostly dispersed and occurring in patches. Most colonies were found to be young and small. The summary of the retrospective analysis for coral reefs is found in Table 6.

Attributed Causes

The seemingly sparse distribution of coral reefs, mostly occurring in patches and in young and small colonies, in the bay could be attributed to various factors including physical destruction (dynamite fishing), cyanide/poison fishing in the reef area, siltation, gathering, use of fishing gears and attachments (trawls and motorized pushnets), increase in boat anchorage, and pollution from metals, pesticides and oil spills. Further analysis of species composition and identification of dominant species could provide insights into environmental characteristics of different reef areas and aid in identifying major causes of decline in different locations.

Table 6. Retrospective Analysis for Coral Reefs in Manila Bay.

Habitat Type	Areal Extent	Results		Impact
		Change/s Observed	Identified Agent/s	
Coral Reefs	Small	Quantity: there was decline but no actual/estimated figures available/ecological status categorized as poor As of 1992 – 1993: • percent live cover: 20 in Mariveles, 40 to 80 in Cavite (Limbones Cove), and 20 in Corregidor Island • 14 families of hard corals, one family for soft coral composed of 38 genera and 53 species Quality: No data Information from available relevant literature/studies: • structure: fringing type composed of generally encrusting and massive in habit / no solid stands / dispersed and occurring in patches / most colonies young and small	• Physical destruction (i.e., dynamite fishing) • Cyanide/poison fishing in the reef area • Siltation • Gathering • Fishing gears and attachments (trawls and motorized pushnets) • Increased boat anchorage	• Degradation or loss of habitat • Reduced fishery production • Reduced tourism potential • Reduced physical protection • Reduced biodiversity • Loss of carbon sequestration

Source: BFAR, 1995.

Consequences

The consequences of coral reef degradation or loss are reduced biodiversity, reduced fishery production, reduced tourism potential, and reduced physical protection.

Seagrass beds

Evidence of Decline

Available data (BFAR, 1995) only include information on species, abundance, and diversity. *Halophila ovalis* and *Halodule pinofolia* were the two dominant species found in the sampling stations at the mouth of the bay (Orion-Mariveles-Corregidor-Limbones cove area). Limbones had the highest recorded abundance, 23 ind/0.5 m^2, followed by Orion, 12 ind/0.5 m^2, and with Mariveles and Corregidor the lowest at 5 to 6 ind/0.5 m^2. Generally, the diversity was categorized as low; Orion, Limbones, and Corregidor were found to have 0.59 to 0.69 diversity indices, while Mariveles had a very low index (0).

Since there were no available estimates of areas previously covered by seagrasses in Manila Bay, estimates of losses cannot be obtained. The results of the assessment are found in Table 7.

Table 7. Retrospective Analysis for Seagrass in Manila Bay.

Habitat Type	Areal Extent	Findings		Impact
		Observations	Possible Agent/s	
Seagrass	Small	Available Information: Only five species – • Dominated by two (2) species - *Halophila ovalis* and *Halodule pinofolia* • Abundance (ind/0.5 m^2): Orion, Bataan – intermediate (12) Mariveles, Bataan – low (5 and 6) Limbones - high (23) Corregidor Island – low (5 and 6) • Diversity Index: Orion, Bataan – high (0.59 – 0.69) Mariveles, Bataan – low (0) Limbones - high (0.59 – 0.69) Corregidor Island – high (0.59 – 0.69) Over-all – low diversity	Most likely: • Sedimentation Others: • Conversion of coastal areas for open water fish culture • Dynamite fishing and other destructive fishing methods • Discharge from domestic and sewage or industrial wastes: - Oil and Grease - Oil Spills - Heavy Metals - Pesticides - PAH	• Loss of economically important species • Loss of shoreline protection (stabilizes the action of waves) • Lost of habitat and nursery grounds • Reduced detritus

Source: BFAR, 1995.

Attributed causes

Sedimentation is a potential factor for causing a possible decline in seagrass in the bay. Other factors include conversion of coastal areas for open water fish culture, dynamite fishing and other destructive fishing methods, and pollution of the water and sediment with oil and grease, oil spills, heavy metals, pesticides and PAHs.

Consequences

Decline in seagrass will lead to the loss of economically important species, loss of protection (as it stabilizes the action of waves), loss of habitat and nursery grounds, and reduction in detrital matter.

Soft-Bottoms

Evidence of Decline

The soft-bottom communities are composed of the benthic organisms made up of an assemblage of invertebrate organisms. The distribution and seasonal variation of the soft-bottom fauna may depend on several environmental factors such as temperature, salinity, character of the substrate, seasonal changes and others.

The results of the Resource and Ecological Assessment of Manila Bay (BFAR, 1995), conducted from July 1992 to October 1993, showed how the distribution of organisms in the bay were influenced by environmental conditions.

In general, there was no significant seasonal variability in the mean population density of the soft-bottom benthos, but there were significant differences in population density and distribution between stations, with Corregidor recording the highest mean population density of the major groups of soft-bottom fauna and Navotas having the lowest density for the same groups of organisms. For example, in May 1993, there were 7,351 ind/m^2 in Corregidor and 45 ind/m^2 in Navotas. This may be ascribed to the nature of the substrate. Heterogeneity in sediment composition promotes habitat diversification. The substrate of Corregidor was composed of grains that were not well-sorted while the substrate in Navotas was fine-grained and clayey. Aside from this factor, however, the study also showed that the contrast in population densities might be indicative of the existing environmental conditions. Based on the water quality study, Corregidor had nearly pristine ecological conditions while Navotas had very poor water quality.

The study also showed that there were highly tolerant assemblages that prevailed in muddy substrates near sewerage, organic waste and effluent outfalls, and that there were other communities that dominated areas with good sediment sorting and less environmental disturbances.

A more recent study, the Pasig River Rehabilitation Project (PRRP, 1999), conducted from 1996 to 1998, showed that for the major taxonomic groups of benthos (polychaeta, bivalvia, gastropoda and crustacea), there was a decline in terms of mean abundance and mean biomass.

Mean abundance declined from 706 and 690 total/m^2 in March and September/October 1996, respectively, to 214 and 140 total/m^2 in April and September 1997, and 50 and 118 in March and November 1998.

There was also a decline in mean biomass from 22 and 98 grams wet weight per square meter (g ww/m^2) in March and September/October 1996, respectively to 8.2 and 9.5 (g ww/m^2) in April and September 1997, and 7.9 and 1.0 in March and November 1998 (g ww/m^2).

There was also a noted shift, in terms of community structure, from a bivalve-dominated community to an increasingly polychaete-dominated community. Table 8 details the retrospective analysis for soft-bottoms in Manila Bay.

Attributed causes

Pollution has been identified to cause the decline in benthos, particularly manifested in the low dissolved oxygen levels in the bay waters. The low DO, especially at the bottom, creating almost anoxic conditions is due to the continuous organic loading in the bay and the consequent high biochemical oxygen demand (BOD) and chemical oxygen demand (COD) particularly in areas where major rivers drain. Other pollutants like oil and grease, heavy metals, pesticides, PAHs and the solid wastes that accumulate at the bottom may also have affected the quality and quantity of the benthos, with consequent effects on demersal fish catch.

Other important agents that caused the decline in benthos were sedimentation and physical disturbance. Heavy sedimentation is associated with reclamation activities particularly in the urban areas and physical disturbance/destruction is associated with trawl fishing, use of motorized pushnets and other activities that disturb the bottom sediments.

Consequences

A study (BFAR, 1995) has shown that the composition of the soft-bottom community has an effect on the fisheries. A positive correlation was reported between mean catch rate of demersal fish stock and benthos population density ($r - 0.95$, $P < 0.05$) and species diversity (BFAR, 1995). It was noted that in areas where there was high benthos population density and species diversity, fish catch rates were also high. While in areas near discharge or outfalls of sewers and in pollution sinks, which have observed high concentrations of heavy metals and other debris, there was low benthos density and low fish catch.

Benthic organisms also play a significant role in the degradation of organic materials in the sediment and, therefore, aid in the regulation of organic load. The loss of benthos has consequent effects on this important ecological function.

Table 8. Retrospective Analysis for Soft-Bottoms in Manila Bay.

Habitat Type	Areal Extent	Findings		Impact
		Observations	Possible Agent/s	
Soft Bottoms	Large	• 1992 – 1993 (BFAR, 1995): Significant differences in mean population density between stations - Corregidor-highest density - Navotas-lowest density Different dominant communities between stations • 1996 – 1998 (PRRP, 1999): Quantity: - Decline in mean abundance of major taxonomic groups (total/m^2): 706 and 690 for Mar. and Sept./Oct. 1996, respectively to 214 and 140 in Apr. and Sept. 1997, resp., to 50 and 118 in Mar. and Nov. 1998, resp. - Decline in mean biomass of major taxonomic groups (g ww/m^2): 22 and 98 in Mar. and Sept./Oct. 1996, resp. to 8.2 and 9.5 in Apr. and Sept. 1997, resp., and 7.9 and 1.0 in Mar. and Nov. 1998, resp. Quality: Community structure - dominated by polychaetes/ low species diversity	Most likely: • Low DO • Sedimentation (reclamation activities) • Physical Disturbance (fishing activity) Possibly: • Pollution: Oil and Grease Heavy Metals / Pesticides Other organics PAH TSS	• Degradation or loss of habitat • Loss of benthic organisms, reduced diversity • Decline in fish production • Loss of function in regulation of organic loading

Sources: BFAR, 1995 and PRRP, 1999.

Mudflats, Sand flats, Beaches, and Rocky Shores

Based on the Resource and Ecological Assessment of Manila Bay (BFAR, 1995), the total area occupied by mudflats is estimated to be around 4,600 ha. Fifty three percent (53%) of the mudflats are found in Bulacan, 29% in Pampanga, and 17% in Bataan. Based on the same study, total sand flat area is 1,500 ha, and this composite is distributed in Bataan (47%), Cavite (36%), and Metro Manila (16%), while none are found in Pampanga and Bulacan. There were no estimates made on beach areas, but the same study mentioned particular areas in Ternate, Cavite and southern part of Metropolitan Manila, as well as in Cochinos Point in Mariveles, Bataan. In addition, these areas were found to have composite floral cover of herbs (62.20%), trees (21.50%), shrubs (9.50%), and vines (7.80%).

There is paucity of data on the location, condition and area occupied by rocky shores in Manila Bay. Although based on maps available, the area of such habitats is quite small. These are considered as least important – and therefore least studied – compared with other habitats or resources found within the bay.

Table 9. Retrospective Analysis for Mudflats, Sand flats, Beaches, and Rocky Shores in Manila Bay.

Habitat Type	Areal Extent	Findings		Impact
		Observations	Possible Agent/s	
Mudflats	Moderate	Total Area: 4,600 ha Bulacan: 2,457 ha Pampanga: 1,340 ha Bataan: 803 ha	Reclamation Conversion	Degradation and/or loss of habitat
Sand flats / Beaches	Small	Total Area: 1,500 ha Bataan: 723 ha Cavite: 537 ha Metro Manila: 240 ha Composite floral cover: herbs (62.20%), trees (21.50%), shrubs (9.50%), and vines (7.60%)	Reclamation Conversion Pollution	Degradation and/or loss of habitat
Rocky Shores	Small	Total Area: no data Location: Ternate Cavite, southern part of Metropolitan Manila, and Cochinos Point, Mariveles Bataan	Reclamation Conversion Physical Destruction	Degradation and/or loss of habitat

Source: BFAR, 1995.

Evidence of Decline

Estimates of loss or degradation of mudflats, sand flats, beaches, and rocky shores cannot be obtained since there was insufficient comparable information. Table 9 provides the findings of the retrospective analysis for each of the aforementioned habitats.

Attributed causes

Reclamation activities and continuous conversion, and in some cases, pollution, may contribute to the degradation or loss of these habitats.

SUMMARY

Resources

For resources, a clear evidence of decline was established for fisheries (BFAR, 1995; Tambuyog, 1990; and FSP-DA, 1992) and shellfisheries (BFAR, 1995; UNEP/EMB-DENR, 1991; Tambuyog Development Center, 1990; and Blanco, 1947). The adverse ecological, economic, and social consequences of decline in the two resources are both considered large even if shellfisheries are limited to certain parts of the bay only and are small in terms of areal extent.

There were no available comparative data on phytoplankton density and diversity to suggest a decline of phytoplankton in Manila Bay, but based on increasing chlorophyll-a measurements from 1996-1998 (PRRP, 1999), phytoplankton was not a resource at risk in the bay.

There were no information on previous extent of cover and distribution of seaweeds in the bay so retrospective risk assessment could not be carried out.

Table 10. Summary of evidences of decline, areal extents, and the consequences in the decline of resources in Manila Bay.

Resource	Evidence of Decline	Areal Extent (Distribution)	Consequences of Decline		
			Ecological	Economic[a]	Social
Fisheries	Much	***	***	***	***
Shellfisheries	Much	*	***	***	***
Seaweeds	No data	*	**	**	*
Phytoplankton	No data	***	***	-	-

* - small
** - moderate
*** - large

[a] - market values

Table 10 presents how much information was available to establish decline in the resources, the areal extent of distribution of the resources in the bay, and the ecological, economic and social consequences of decline that has occurred for fisheries, shellfisheries and benthos, might have occurred for seaweeds, or might occur for phytoplankton. The economic consequences refer to the market values of the particular resource and do not include non-market values such as option and existence values. For example, the economic consequence of decline in seaweeds was considered moderate because this was based on the market value of the seaweeds and did not consider the loss of ecological functions and contribution to decline in fisheries.

Habitats

For habitats (Table 11), clear evidence of decline was established only for mangroves (BFAR, 1995). For coral reefs, there were no records of the previous extent of cover but there were unpublished accounts indicating that there had been a decline in the quality and cover of the reefs. This destruction of mangroves and coral reefs will have large ecological consequences due to the loss of their ecological functions as breeding, spawning and nursery grounds for various marine life.

For soft-bottoms, a study conducted in 1992 – 1993 (BFAR, 1995) showed significant contrast in population densities and dominant communities for areas in the bay with nearly pristine ecological conditions (e.g. Corregidor) and areas with very poor water quality (e.g. Navotas). Data from 1996-1998 (PRRP, 1999) showed evidence of decline in mean abundance and mean biomass of the major taxonomic groups and in species diversity. This decline in benthos will have large ecological consequences as shown in a study (BFAR, 1995) that presented the relationship between benthos and fish productivity in Manila Bay. Fish catch was higher in areas where there was high benthos population density and species diversity and fish catch was low in pollution sinks like sewers and discharge outfalls.

For the other habitats (e.g., seagrass, mudflats, sandflats and beaches, and rocky shores), retrospective risk assessment could not be carried out due to lack of comparative information to determine what changes have taken place.

Table 11 shows the amount of evidence used to establish decline in the habitats, the areal extent of distribution of the habitats in the bay, and the ecological, economic and social consequences of decline that has occurred for mangroves and coral reefs, or might have occurred for the other habitats. As discussed for the resources, the economic consequences of decline refer only to the market values of the particular habitat.

Table 11. Summary of evidences of decline, areal extents, and the consequences in the decline of habitats in Manila Bay.

Habitat	Evidence of Decline	Areal Extent (Distribution)	Consequences of Decline		
			Ecological	Economic^a	Social
Mangroves	Much	*	***	**	**
Coral Reefs	Little	*	***	**	*
Seagrass beds	None	*	**	*	*
Soft –bottoms	Moderate	***	***	-	-
Mudflats	None	**	**	**	*
Sandflats / Beaches	None	*	*	**	**
Rocky Shores	None	*	*	*	*

* - small

** - moderate

*** - large

^{a} - market values

Prospective Risk Assessment

INTRODUCTION

A prospective risk assessment aims to determine if measured or predicted levels of environmental parameters are likely to cause harm to targets of interest. This is accomplished by identifying the likely targets then comparing the measured or predicted environmental concentrations (MECs or PECs) with appropriate threshold values (PNECs) to get risk quotients (RQs). For human health, risk through seafood ingestion is estimated by comparing measured or predicted environmental levels (MELs or PELs) with levels of concern (LOCs) as PNECs.

In an ecological point of view, different thresholds should be specified for different targets, and if these are not available, as is often the case, ecotoxicological endpoints can be extrapolated to ecosystem endpoints using appropriate application factors (MPP-EAS, 1999a).

For Manila Bay, a simplified ecological risk assessment was carried out using standards and criteria values from the literature as thresholds to estimate the risk to the entire ecosystem. The principles and techniques applied are described in MPP-EAS (1999a).

For the ecological risk assessment, RQs are the ratios of MECs (or PECs) and PNECs. For human health, RQs are the ratios of MELs (or PELs) and LOCs. LOCs are obtained by dividing the tolerable daily intakes (TDIs) by the consumption rates. When an RQ is less than 1, it is presumed that the likelihood of adverse effects is low. When an RQ is greater than 1, there is a likelihood of adverse effects the magnitude of which increases with increase in RQ.

For ecological risk assessment:

$$RQ = \frac{MEC(orPEC)}{PNEC}$$

For human health:

$$RQ = \frac{MEL(orPEL)}{LOC}$$

Where RQ < 1 Low risk
≥ 1 High risk

The reliability of the assessment depends largely on the quality of the data used as MECs and on the quality and relevance of the threshold values used as PNECs. Although there may be uncertainties associated with the MECs and PNECs used in the risk assessment, the utility of the RQs in signalling potential areas of concern is significant. The uncertainties can be minimized through the careful selection of good quality data and relevant thresholds or these can be described so that future use of the results of the risk assessment would take the possible effects of the uncertainties into consideration.

Uncertainties can also arise from the variability in the RQs obtained. An initial measure of uncertainty was obtained by taking the average and worst-case (maximum) RQs. A more quantitative measure of uncertainty can be carried out using the Monte Carlo estimation, a resampling technique which randomly re-samples pairs of MECs and PNECs to come up with the percentage of the measured values exceeding the threshold.

Data for the initial risk assessment of Manila Bay came primarily from the Pasig River Rehabilitation Project Report (PRRP, 1999). A description of the data and sampling locations for PRRP and other references can be found in Appendix 2.

The threshold values used as PNECs came from various sources (Appendix 4) and will be detailed in the discussion for each parameter. Included in Appendix 4 is the Philippine Water Quality Criteria (DENR Administrative Order No. 34 or DAO 34, 1990). In the DAO 34, criteria values are given for different water classifications based on current best beneficial use. Water classifications are arranged in the order of the degree of protection required, with Class SA having generally the most stringent quality for marine/coastal waters, and Class SD having the least stringent water quality for marine waters. For freshwaters, Class AA and Class D are the most stringent and least stringent classifications, respectively.

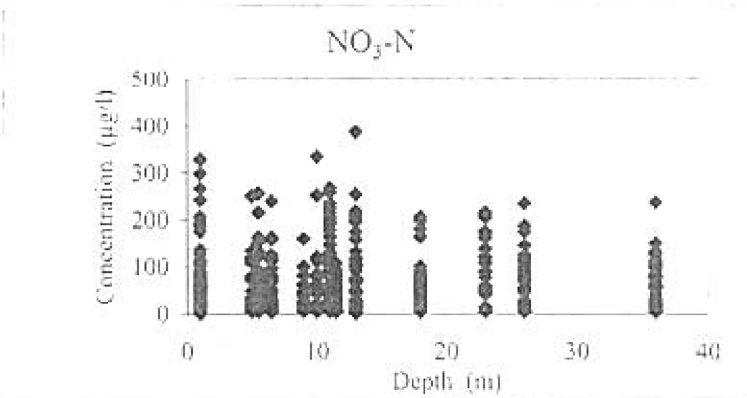
NUTRIENTS

Water Column

The data for nutrients in the water column were taken from the PRRP Report (1999). The data used was obtained monthly from eight stations spread across the bay from 1996 to 1998. The criteria values were from the proposed ASEAN Marine Water Quality Criteria (Jusoh et al, 1999).

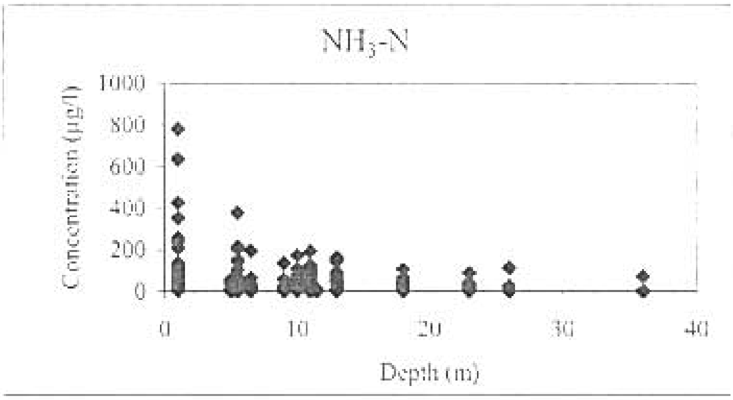
Initial assessment of the quality of the data using scatter plot distributions (Figures 3a, 3b, 3c), showed that the maximum values (MEC_{Max}) seemed to be outliers. A closer inspection of the data for PO_4 revealed that 30 % of the data was not dissolved inorganic PO_4 but particulate PO_4, and this is where most of the high values came from. This information was stated in the text of the report but was not readily known from the data tables. This emphasizes the need for a more thorough review of data employed in risk assessment calculations. The RQs reported here for PO_4 were calculated after the particulate data and another outlier (high value coming from a relatively cleaner station) were taken out. For the other nutrients, it was not easy to take out suspected outliers because the maximum concentrations were measured from expected hot spots. These high values were, therefore, retained and used to calculate the RQ_{Max}.

Figure 3a. Scatter plot of data for NO_3-N.



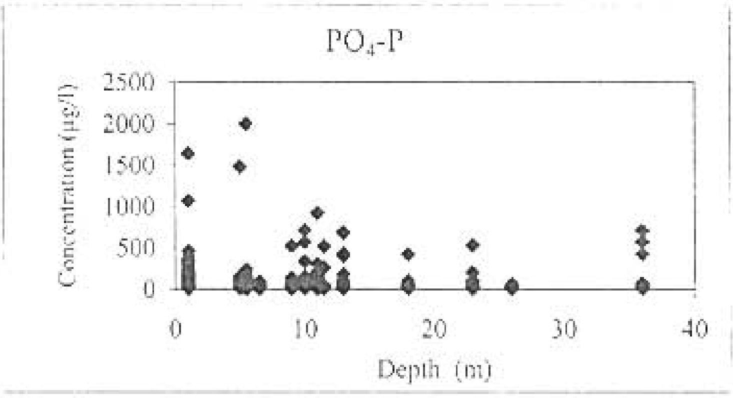
Source: PRRP, 1999.

Figure 3b. Scatter plot of data for NH_3-N.



Source: PRRP, 1999.

Figure 3c. Scatter plot of data for PO_4-P.



Source: PRRP, 1999.

The RQ_{Max} for nutrients, therefore, represent only the areas were the measurements were taken. A better representation of nutrient conditions in the bay would be the $RQ_{geomean}$ which was calculated using the geometric mean of the measurements.

The average and maximum RQs for the nutrients are given in Table 12. All the values for the worst-case RQs for nutrients are greater than 1. Phosphate indicates significant concern because the maximum RQ is very high ($RQ_{worst\text{-}case} = 146$) and the average RQ was also greater than 1. The $RQ_{Geomean}$ for NO_3 ($n = 772$) and NH_3 ($n = 766$) were less than 1. This shows that, on average, the environmental concentrations for the two parameters are below the critical level. Phosphate ($n = 558$) on the other hand exceeded 1 ($RQ_{Geomean} = 5.9$). Thus, phosphate is an important agent of concern.

Table 12. RQs of Nutrients in Manila Bay.

Agent	$MEC_{Geomean}$ (mg/l)	MEC_{Max} (mg/l)	PNEC (mg/l)	$RQ_{Geomean}$	RQ_{Max}
NO_3-N	0.027	0.387	0.06	0.4	6
PO_4-P	0.029*	0.714	0.0049	5.9	146
NH_3-N	0.003	0.779	0.070	0.04	11

* PO_4 $MEC_{Geomean}$ is the average of 3 geometric means (total n = 558)
Source for MEC: PRRP (1999).
Source for PNEC: Jusoh et al., 1999.

The maximum MEC for PO_4 was sampled from the bottom in a station near Bulacan River. Data from other depths in the water column taken on the same outing were much lower so there is reason to suspect that the high value might have been due to remineralization from the sediment. A more detailed analysis of vertical and horizontal variability in the water column as well as temporal variability may be able to verify these statements.

The possible sources of nutrients in Manila Bay are domestic/commercial/institutional waste and sewage, untreated or partially treated industrial effluents and agricultural discharge or run-off.

All of these are contributing significant amount of nutrients to the bay, but domestic/commercial/institutional waste and sewage can be considered as the major sources of contaminants and these can be discharged or transported to the bay through the river systems.

With regard to phosphate, elevated values in the water column can be attributed to the extensive use of feeds, fertilizers and detergents with high phosphate contents.

Nutrients are required for primary productivity but elevated concentrations may cause eutrophication and may trigger phytoplankton blooms. This has implications on dissolved oxygen levels in the bay and, eventually, on the benthos and other sessile organisms.

Uncertainty Analysis

The risk quotients obtained highly depend on the MECs and PNECs employed in the calculations. Some of the values used in the assessment for NO_3 and NH_3 were suspected to be outliers, as shown in the scatter plots (Figure 3a - c). For NH_3, values greater than 300 µg/l represent approximately 1% of the total sample size (n = 778). These high values, however, were taken from stations near the major rivers so these were retained to prevent disregarding values that may represent real hot spots. A more refined risk assessment is in order, focused on verifying the values used in this initial risk assessment and on a more detailed analysis of spatial and temporal variations to enable the identification of possible sources as well as determination of natural seasonal variability. Loadings from major rivers can also be evaluated to determine their relative contributions to nutrient levels in the bay. An alternative method that can identify whether nutrients in the bay are coming from sources inside or outside the bay is the calculation of nutrient budgets in the bay. This would be a useful support to, as well as a means to verify, the assessments made on the bay. This, however, would need nutrient data from sediment interstitial waters.

The PNEC used for phosphate (0.015 mg/l PO_4) is the proposed criteria value for coastal waters. There is another proposed criteria for estuarine waters (0.045 mg/l PO_4) that could considerably reduce the RQs for phosphate, but there are reservations in using this for Manila Bay since the bay is relatively better mixed and flushed than the typical estuary.

DO/BOD/COD

Water Column

For dissolved oxygen, unlike with the other parameters, concentrations lower than the threshold value signal deteriorating environmental conditions. RQ, therefore, is not the ratio of MECs and PNECs, but the reciprocal of the ratio. For BOD and COD, RQs cannot be calculated because there are no available data from the bay. Contributions from major rivers draining into the bay will be considered instead.

The data used was from the PRRP Report (1999) and was taken at the same time as the nutrient data. The criteria value was from the DAO 34 (1990) for Class SC waters.

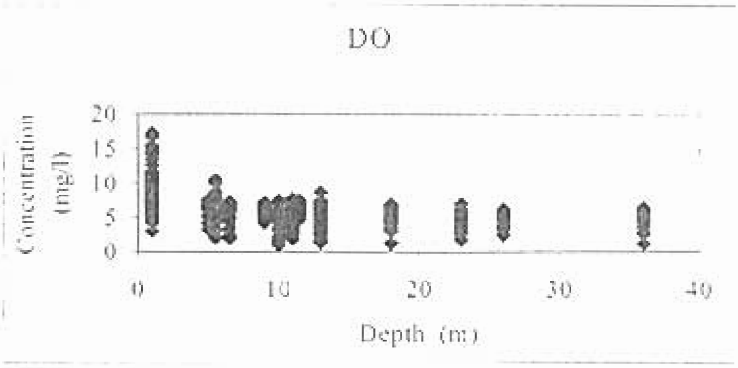
The RQ_{Max} for dissolved oxygen (DO) exceeded 1 (RQ_{Max} = 5) while the $RQ_{geomean}$ (n = 756) is approaching 1 (Table 13). The highest RQ was obtained for a measurement near the bottom at the station near Bulacan River. The scatter plot (Figure 4) shows the distribution of DO values at the surface, mid-depth and near-bottom. Most of the high RQs were obtained from bottom DO measurements although some high RQs were obtained from mid-depth and a few from the surface. An uncertainty analysis would be needed to determine the probability of the RQ value exceeding 1 for the whole data set and also for the different depths.

Table 13. RQs of Oxygen Demand Parameters in Manila Bay.

Agent	$MEC_{Geomean}$ (mg/l)	MEC_{Max} (mg/l)	PNEC (mg/l)	$RQ_{Geomean}$	RQ_{Max}
BOD	No data				
COD	No data				
DO	5.78	1.00	5.0	0.87	5.0

Source for MEC: PRRP (1999).
Source for PNEC: DAO 34 (1990) for Class SC waters.

Figure 4. Scatter plot of DO in Manila Bay



Source: PRRP, 1999.

The results for DO may reflect the possible BOD/COD profiles of the bay since increase in the organic load associated with the high BOD values can significantly cause depletion of DO.

The depletion of DO in the water column can be attributed to the possible sources of nutrients as mentioned above.

The low levels of DO in the bay, especially in bottom waters, may have significant adverse consequences on the benthos and shellfisheries and, indirectly, on the organisms that feed on the benthos. Low DO also has implications on the decomposition of organics in the bay and may promote anoxic conditions, which also adversely affect aesthetics.

Uncertainty Analysis

Since the $RQ_{Geomean}$ was very close to one, the Monte Carlo estimation was applied. The results showed that the probability of RQ exceeding 1 is approximately 40% (S.D. = 1.94). A more detailed spatial analysis would identify the areas in the bay where low DO occurs most frequently and a more detailed temporal analysis would establish how long the DO stays at low concentrations that could adversely affect the organisms in the bay.

Consideration of Contributions from Four Major River Systems

To corroborate the assessment of nutrient and oxygen demand in the bay, nutrient, DO and BOD measurements from four rivers systems considered as major pathways of materials to the bay were also assessed. There were no measurements for COD. The BOD assessment is particularly important since this parameter could not be assessed in the bay due to lack of data. Contributions from major rivers would give the potential BOD scenario inside the bay.

The data used to compute for RQs were average values of measurements from 1991 to 1999 from different stations in each river system. The criteria values used were for Class C of the DAO 34 (1990) water quality criteria for fresh waters.

Nutrients

The maximum MECs for all the nutrient parameters (Table 14) were derived from the mean of the maximum concentration of different stations in each river system from 1996 to 1998 except for Metro Manila (1990-1998). The geometric mean was calculated based on the average concentration of nutrients from different stations in each river system. The criteria values used were 10 mg/l for nitrate-N and 0.4 mg/l for phosphate-P. The criteria value used for NO_3-N, however, applies only to lakes and reservoirs and similarly impounded waters and is more conservative.

All calculated maximum RQs for PO_4-P were greater than 1 in all river systems examined. Average PO_4-P RQs for the Cavite and Pampanga river systems were less than 1 while average RQs for Bulacan and Metro Manila river systems were 4.24 and 1.22, respectively. All maximum NO_3-N RQs were less than 1 except in the Metro Manila River System (RQ_{Max} = 1.26). Average NO_3-N RQs for all the river systems were less than 1. There are no environmental criteria for ammonia in the water column, thus the RQ value for this parameter was not calculated.

Based on MECs, nitrogen in most of the river systems appears to have higher concentrations than P, but RQ values suggests that the level of P can pose a risk to the water column. Higher concentrations of P than N were only observed in the Bulacan River System.

The results of the risk assessment for the river systems confirm the greater level of concern for PO_4 that was shown in the risk assessment for Manila Bay. It also focuses attention on the potential contributions of the different major rivers although the data used were not sufficient to establish the relative contributions. Reports of nutrient river loadings would be needed for such assessments.

Table 14. RQs for Nutrients in Four Major River Systems.

Agent	$MEC_{Geomean}$ (mg/l)	MEC_{Max} (mg/l)	PNEC (mg/l)	$RQ_{Geomean}$	RQ_{Max}
Cavite					
NO_3-N	0.29	4.83	10	0.03	0.5
PO_4-P	0.24	1.26	0.4	0.6	3
NH_3-N	0.05	2.85	No data		
Bulacan					
NO_3-N	0.05	2.41	10	0.005	0.2
PO_4-P	1.70	9.17	0.4	4	23
NH_3-N	1.07	4.14	No data		
Pampanga					
NO_3-N	0.13	0.667	10	0.01	0.07
PO_4-P	0.12	0.495	0.4	0.3	1.2
NH_3-N	0.02	0.441	No data		
Metro Manila					
NO_3-N	0.38	12.60	10	0.04	1.3
PO_4-P	0.49	7.26	0.4	1.2	18
NH_3-N	1.29	45.00	No data		

Sources for MEC: Pasig River Rehabilitation Secretariat (unpublished).
Sources for PNEC: DAO 34, 1990, for Class C waters.

Uncertainty Analysis

The data used to obtain the geometric means of all the nutrient parameters for all the river systems were average values for each of the stations in the rivers. Since these were arithmetic means, the values may have been biased toward the higher values. A refined risk assessment should use the raw data to get a more accurate estimate of environmental risk from nutrients.

The criteria values given in the DAO 34 for Class C waters also seemed rather high (10 mg/l for $N0_3$-N and 0.4 mg/l for PO_4-P) but these were the only criteria available for fresh water when the initial risk assessment was conducted. It would be useful to compare these values with other nutrient criteria for fresh water.

BOD/DO

All maximum RQ values for BOD and DO were greater than 1 (Table 15). Of the four river systems, the Metro Manila river system (Pasig River and major tributaries) had the highest BOD (RQ = 27.14) followed by the Bulacan river system (RQ = 17.14). Consequently, both river systems also gave the lowest DO (MEC = 0) in the water column. For the computation of RQ, the zeros were replaced with 0.01. The RQs obtained for DO were very high (RQs = 500) and suggests a need for immediate action.

Bulacan, Metro Manila and Pampanga River Systems had average DO RQs greater than 1 while Cavite River System had average DO RQ that was approaching 1 ($RQ_{Geomean}$ = 0.98). For BOD, the average RQs were greater than 1 for Bulacan and Metro Manila. These parameters should thus be considered as parameters of concern for these systems and also for Manila Bay since loads from the rivers considered eventually end up in the bay.

Table 15. RQs for BOD and DO in Four Major River Systems.

Agent	MEC$_{Geomean}$ (mg/l)	MEC$_{Max}$ (mg/l)	PNEC (mg/l)	RQ$_{Geomean}$	RQ$_{Max}$
Cavite					
BOD	3.04	11.00	7	0.4	2
DO	5.11	0.80	5.0	0.98	6.2
Bulacan					
BOD	18.44	120	7	3	17
DO	0.44	0.01	5.0	11	500
Pampanga					
BOD	2.92	25	7	0.4	4
DO	3.56	0.3	5.0	1.4	17
Metro Manila					
BOD	11.38	190.00	7	2	27
DO	2.78	0.01	5.0	1.8	500

Sources for MEC: Pasig River Rehabilitation Secretariat (unpublished).
Sources for PNEC: DAO 34, 1990, for Class C waters.

Uncertainty Analysis

The Monte Carlo estimation was applied to the DO data from the Cavite river system since the average RQ obtained was close to 1. The results showed that DO has 30% probability of exceeding 1 (S.D. = 1.64).

The preceding analysis, however, may not provide the real scenario in the river systems around the bay since the calculated geometric means were all based on the average concentrations from each river from 1996-1998, which might have introduced some bias toward higher concentrations.

TOTAL SUSPENDED SOLIDS (TSS)

Water column

The data for total suspended solids was from PRRP (1999) and was taken at the same time as the nutrient and DO data used in the preceding sections.

The highest concentration of total suspended solids (TSS) in Manila Bay, equivalent to 1,048 mg/l, was observed in the established monitoring station near the Manila Port Area and Pasig River (14°36'N, 120°54'E). Using a threshold value of 50 mg/l, the interim standard of the Department of Environment of Malaysia (MPP-EAS, 1999b), a maximum RQ of 21 was obtained. On the other hand, the geometric mean of all observations (n=772) was 23.32 mg/l which gave an RQ of 0.5.

Suspended solids refer to organic and inorganic fine solid particles suspended in the seawater and can be filtered through 0.45 μm membrane. These may be produced by natural processes or by human activities. Biological components like the plankton and the excretion and remains of marine organisms contribute to suspended solids. In Manila Bay, suspended solids may also come from domestic sewage and industrial wastes, agricultural and aquaculture activities, influx of large volumes of freshwater with high sediment loads from the watersheds during the rainy season, soil erosion with consequent run-off from land directly into the bay or to its tributaries, coastal erosion due to habitat degradation, reclamation and dredging activities, dynamite fishing, upwelling of sediments due to wind action and movement of boats, and deposition of air-borne pollutants.

Suspended solids render the water turbid and reduce light penetration and visibility, a condition also associated with low dissolved oxygen and increased anaerobic conditions. Because of the resultant high turbidity, there is a decrease in primary productivity and in food supply for different trophic levels. The solids also serve as a surface on which oil and other toxic pollutants can be adsorbed. Eventually, the suspended solids may deposit on coral reefs, in effect causing their suffocation and deterioration.

Uncertainty analysis

The threshold value used was an interim value from Malaysia (MPP-EAS, 1999b). It was not clear how this value was obtained and it was difficult to compare this with other criteria since TSS criteria are often not specific values but are concentrations or percentages above the annual or seasonal averages. In the DAO 34 (1990), the criteria value for Class SC requires that TSS concentrations should not be 30 mg/l greater than the annual average. In the proposed ASEAN marine water quality criteria (Jusoh et al., 1999), the TSS concentrations should not be 10 % greater than the seasonal averages. This method of setting the TSS criteria shows that annual or seasonal averages vary between bodies of water and that it is difficult to set a specific value. The risk quotient approach, however, needs a specific threshold value to compute for RQs. To come up with threshold values for Manila Bay using the DAO 34 and proposed ASEAN criteria, the required annual or seasonal averages could be computed, then 30 mg/l can be added to the annual average or 10% can be added to the seasonal averages.

TOTAL ORGANIC CARBON (TOC)

Sediment

Total organic carbon in surface sediment (fine-sized fractions) collected from coastal areas of Manila Bay ranged from 0.40% to 2.84% with a geometric mean (n = 37) of 1.28% based on a paper published by Santiago in 1997. TOC is derived from anthropogenic organic pollutants and biogenic substances from marine and land-based sources. The study showed that %TOC on the western side of the bay, varying from 0.98% to 1.93%, is more homogenous than on the eastern side, where values ranged more considerably from 0.4% to 2.84%. High levels of total saturated hydrocarbons (TSH), total aromatic hydrocarbons (TAH) and total polycyclic aromatic hydrocarbons (TPAH) appear to correlate with high %TOC. Unfortunately, no PNEC value for TOC is available to allow calculation of RQ.

COLIFORMS

Water column

Monthly coliform measurements from 10 stations used for swimming or bathing at the eastern and southwestern section of the bay taken from 1996 to 1998 (PRRP, 1999) were analyzed. The threshold values were from the DAO 34 (1990) for Class SC for total coliform and Class SB for fecal coliform. There was no value set for fecal coliform for Class SC.

Results of the analysis showed that geometric mean counts for total coliforms of 13,488 MPN/100 ml (n = 237) and fecal coliforms of 7,898 MPN/100 ml (n = 237) far exceeded the respective thresholds of 5,000 (Class SC) and 200 MPN/100 ml (Class SB). The calculated mean RQs were 3 for total coliforms and 40 for fecal coliforms. Based on the highest MECs observed, the maximum RQ was 480 for total coliforms and 4,500 for fecal coliforms. These RQs suggest a serious concern for human health risk.

The high bacterial load may be attributed mainly to voluminous sewage and domestic wastes generated from households that discharge directly to the bay or to the drainage and river systems which eventually enter the bay. Other sources include commercial and agricultural establishments such as slaughterhouses, markets, livestock farms, hospitals, and topsoil run-offs.

There are 4 major rivers discharging into the bay. A study on one of these rivers, Pasig River, shows that 60% of the pollution load is contributed by domestic wastes, 35% by industrial wastes and 5% by solid wastes and run-off. The Department of Environment and Natural Resources–National Capital Region (DENR-NCR) reported that the water quality of Tullahan and Parañaque River systems is even worse than that of Pasig.

The government formulated an Action Plan in 1993 to fast-track, among others, the upgrading and expansion of the sewage and sewerage system of the Metropolitan Water and Sewerage System (MWSS) which at present serves only about 10% of Metro Manila households.

Seven of the 10 bathing stations monitored were beach resorts at the southwestern section of the bay. It is believed that responsible agencies including local government units should sanction the owners of resorts or bathing establishments that are not in compliance with the criteria for bathing water quality, and close those that present a clear risk to the public. An intensive information and education campaign should also be conducted to inform the public of the adverse effects of bathing in these contaminated waters.

Shellfish

The data on shellfish are limited to a few observations and represent a few sites at the eastern section of the bay (PRRP, 1999). Based on the available data, however, the bacterial load in shellfish was a serious concern as well. The highest total coliform concentration observed was 16,000,000 MPN from Bacoor, Cavite. For fecal coliforms, the highest concentration of 800,000 was observed also in Bacoor, Cavite. Geometric mean values observed were 56,439 MPN for total coliforms and 15,752 MPN for fecal coliforms. There are no criteria values available for total coliform in shellfish. For fecal coliform, using the European Union limit of 300 MPN (EEC, 1979, cited in MPP-EAS, 1999b) as criteria gave a mean RQ of 53 and a maximum RQ of 2667. These high RQ values indicate the serious health risk posed by consumption of contaminated shellfish from certain areas in Manila Bay. The source of these bacteria can be attributed again mainly to untreated domestic sewage.

Uncertainty analysis

The risk assessment done on the water column was based only on data from the eastern section, the most populated and urbanized area around the bay. The results of the risk assessment, therefore, represent only the Metro Manila area, and cannot be generalized for the whole bay. Data from the other areas of the bay should be gathered for the refined risk assessment.

The data for coliform in shellfish tissue was also limited to a few sites at the eastern section of the bay although these may be the sites where bivalves for commercial purposes are grown and harvested. It would then be useful to ascertain if the sampling sites are the important bivalve-growing areas although there would still be a need to gather data taken from the other areas of the bay.

From the high RQs obtained for water and tissue data and the hazards that such contamination levels pose on human health, risk assessment should be taken further by gathering health data from areas around the bay to determine the extent to which human health has already been affected by bathing in contaminated waters and more importantly, by consumption of contaminated tissue.

PESTICIDES

Water column

Data available for aldrin, 4,4'-DDT, dieldrin, and heptachlor gave values of 0.004, 0.0005. 0.006 and 0.021 ug/l, respectively. Based on initial risk analysis using the marine chronic criteria from the U.S. EPA water quality criteria for regulatory purposes, the maximum RQs obtained were equal to 0.5 for DDT, 3.16 for dieldrin and 6 for heptachlor. There were no marine chronic criteria for aldrin.

Sediment

Concentrations of 16 commonly used pesticides in surface sediment from 10 established monitoring stations (PRRP, 1999) were measured in 1996. Except for alpha-BHC, the values observed were at or near detection limits. PNEC values from the Hong

Kong Interim Sediment Quality Values (EVS, 1996) were available only for 4,4'-DDE and its precursor, 4,4'-DDT. The calculated RQs were 1.8 for 4,4'-DDE and 5.7 for 4,4'-DDT. Calculation of RQ was also made for aldrin, dieldrin and heptachlor using water quality criteria and sediment-water partition coefficient, that estimates the equilibrium partitioning of a chemical between the water and sediment-bound phases, to estimate the critical sediment concentration. The RQ values for these three pesticides were all less than 1.

Tissue

The levels of 16 commonly used pesticides were also measured in shellfish taken from five stations at the eastern section of the bay in 1996 (PRRP, 1999). Tolerable daily intake (TDI) values were available only for aldrin, 4,4'-DDE, 4,4'-DDT, dieldrin, endosulfan 1, endosulfan 2, endosulfan sulfate, and endrin. RQs were calculated for said pesticides using an average consumption rate of 20 g/person/day for shellfish (FNRI, 1987). For all pesticides analyzed with the exception of endosulfan sulfate, the RQ was less than 1. The RQ for endosulfan sulfate was 1.22.

Concentrations of aldrin, alpha-BHC and heptachlor were also determined in fish (Tuazon and Ancheta, 1992). RQs were calculated using a consumption rate of 92 g/person/day for fish (FNRI, 1987). High RQs of 24 for aldrin and 65 for heptachlor were obtained. There was no TDI for alpha-BHC so RQ could not be computed. These results show that the ingestion pathway appears to pose a health risk to the consuming public, at least for aldrin and heptachlor.

The major possible sources of pesticides in the bay are run-offs from agricultural farms in the provinces of Pampanga, Cavite, Bulacan and Bataan. Other sources include agro-based industries engaged in manufacturing pesticides in Bataan and Metro Manila. While not all the pesticide levels observed may be alarming at present, the results of the initial risk assessment signal cause for concern since pesticides can be persistent and the cumulative, chronic effects may become apparent over time.

Uncertainty analysis

There was very limited data for pesticides in water but the RQs obtained from the few data points suggest that this parameter should be examined more closely using additional data. For sediments and tissue, there was relatively adequate number of measurements for 16 pesticides. For some pesticides in tissue, the RQs obtained were high. The tissue data, however, came from the eastern section of the bay only. For the sediments, all the data for which threshold values were available were reported as less than the detection limit (<0.004 mg/kg DW for 4,4'-DDE and <0.010 mg/kg DW for 4,4'-DDT). For computation purposes, however, all the data for 4,4'-DDE and 4,4'-DDT were replaced with 0.0039 mg/kg DW and 0.009 mg/kg DW. The average RQs obtained for these pesticides in sediments were greater than one. It is, however, uncertain if these RQs are indicating risks from these pesticides or showing the need for more sensitive methods of detection. For other pesticides, RQs could not be computed due to lack of threshold values. For some of the pesticides where water criteria were available, threshold values for sediments were estimated using partition coefficients. The RQs obtained for these pesticides were all less than the value "1" although the suitability of the estimated critical sediment concentrations for use as PNECs should still be verified.

Additional data for water and tissue in the other areas of the bay should, therefore, be gathered especially near Pampanga River where there are extensive agricultural activities. More criteria values would also be needed to compute RQs for the other pesticides especially since the RQs presented here indicate the need for a closer inspection of pesticide levels in Manila Bay.

TOXIC ALGAE

Harmful bloom of toxic algae (dinoflagellates) or red tide was first observed in the Philippines in 1983 and, in Manila Bay, in 1987. The latest episode was observed in 1998. Although there are several species of dinoflagellates observed in the Bay, the dominant toxic species is *Pyrodinium bahamense var. compressum*. The toxin produced by these species is saxitoxin and neosaxitoxin which cause paralytic shellfish poisoning (PSP). Between the period 1988 to 1999, 30 deaths out of a total of 46 deaths due to PSP nationwide were attributed to contaminated shellfish from the Bay. In addition, there were 706 cases of PSP nationwide who survived, 472 of whom ingested contaminated shellfish from the Bay. The limit imposed by the Bureau of Fisheries and Aquatic Resources is 40 μg toxin/100 g of shellfish meat or 200 MU/100 g of shellfish meat by live mouse bioassay.

The sources of toxic algae or the causes for its bloom have not been clearly established. Eutrophication, and in particular increased phosphorus, climatological changes, and transport processes which cause the algal cysts on the surface sediment to be resuspended into the water column, are subject of continuing studies. Models are also being developed to aid in predicting harmful algal blooms.

HEAVY METALS

Water Column

Concentrations of several heavy metals were measured in water samples taken from three locations in the bay (EMB-DENR, 1991) and different river mouths (BFAR, 1995). Criteria values from several sources were available only for copper (Cu), lead (Pb), zinc (Zn), cadmium (Cd), and silver (Ag). The marine chronic criteria of the USEPA water quality criteria for regulatory purposes, the most conservative values, were used. These values are very similar to the ASEAN Proposed Marine Water Quality Criteria. There was no chronic criteria value for silver so the acute criteria value was employed. The RQs for these metals are shown in Tables 16 and 17.

Table 16. RQs of Heavy Metals in Manila Bay.

Heavy Metals	MEC$_{Geomean}$ (µg/l)	MEC$_{Max}$ (µg/l)	PNEC (µg/l)	RQ$_{Geomean}$	RQ$_{Max}$
Cu	0.15	0.2	2.9	0.050	0.07
Pb	0.6	0.8	5.6	0.1	0.1
Zn	0.14	0.43	55	0.0030	0.010
Ag	0.04	0.05	2.3	0.02	0.02
Cd	0.10	0.11	9.3	0.010	0.010
Mn	0.5	0.6	-	-	-
Fe	0.43	1.7	-	-	-
Co	23	24	-	-	-
U	1.2	1.4	-	-	-

Sources for MEC: EMB-DENR, 1991.
Sources for PNEC: U.S. EPA Water Quality Criteria for Regulatory Purposes.

Table 17. RQs of Heavy Metals in River Mouths.

Heavy Metals	MEC$_{Geomean}$ (µg/l)	MEC$_{Max}$ (µg/l)	DAO 34 (Phil.)			U.S. EPA marine chronic criteria		
			PNEC (µg/l)	RQ$_{Geomean}$	RQ$_{Max}$	PNEC (µg/l)	RQ$_{Geomean}$	RQ$_{Max}$
Cu	4.9	46.5	50	0.098	0.93	2.9	1.7	16
Pb	13.2	13.8	50	0.26	0.28	5.6	2.4	2.5
Zn	26.0	42.5				55	0.47	0.77
Ag	-	-		-	-		-	-
Cd	0.8	1.6	10	0.08	0.2	9.3	0.09	0.17
Mn	-	-	-	-	-	-	-	-
Fe	-	-	-	-	-	-	-	-
Co	-	-	-	-	-	-	-	-
Hg	0.6	1.0	2	0.3	0.5	-	-	-

Sources for MEC: BFAR, 1995
Sources for PNEC: DAO 34, 1990 and U.S. EPA Water Quality Criteria for Regulatory Purposes.

For water samples taken in Manila Bay, Bacoor has the highest concentrations of all the metals studied. Results, however, showed that all maximum RQs were far lower than 1, the highest being 0.1 for Pb and the lowest 0.010 for Zn.

For water samples taken from the river mouths on 2 sampling periods (Sept.-Oct. 1992 and Feb.-Mar. 1993), the highest concentrations of Cu and Pb were found in Cavite, Zn and Hg in Pampanga, and Cd in Metro Manila. These metal concentrations are higher than the concentrations inside the bay. Based on the available PNECs for Class C water (Philippines), however, all the calculated maximum RQs were still below one, with the highest RQ of 0.93 for Cu. The smallest maximum RQ of 0.2 was obtained for Cd. The criteria used for Cu was for Class SC water (marine water) because there was no Cu criteria for Class C (fresh water), although criteria values for the two classifications for the other metals were the same.

The U.S. EPA marine chronic criteria for water was also used as PNEC and the results were average and maximum RQs greater than one for Pb (RQ$_{Max}$ = 2.5; RQ$_{Geomean}$ = 2.4) and Cu (RQ$_{Max}$ = 16; RQ$_{Geomean}$ = 1.7) although Cu is an essential metal and may not pose a significant problem. Although the criteria values are for marine waters, the results gave an indication of the range of RQs that would be obtained if criteria values that differ in degree of protectiveness were used.

Uncertainty Analysis

The RQs for heavy metals in Manila Bay waters indicate low concern for this parameter although limited data was used for the risk assessment. The results, therefore, need to be verified especially when more recent data becomes available. The RQs obtained for heavy metals in the river samples using two sets of criteria also demonstrate the uncertainty associated with the values used as PNECs.

Sediment

The data used in this assessment came from the PRRP Report (1999), BFAR (1995), EMB-DENR (1991), Prudente et al. (1994) and Narcise and Jacinto (1997). The criteria values used were from the Hong Kong Interim Sediment Quality Values or ISQVs (EVS, 1996).

The RQ_{max} (Table 18) for Cd and Cu were obtained (RQs equal to 36 and 12, respectively) at stations near Bataan although it was only Cu that gave an RQ greater than 1. It may be worth mentioning that the maximum MEC for Cd, measured in March 1998 was suspected to be an outlier. It was four orders of magnitude greater than the five other measurements done in the same location on September 1996 to March 1997 and September 1998 (all below detection limit). The RQ obtained if the highest Cd concentration is considered an outlier and the next maximum value is used can also be found in the table. For Cu, although the RQ_{max} was obtained from a station on the western side (Bataan) of the bay, elevated concentrations were also measured in the eastern side, particularly in Metro Manila.

Table 18. RQs of Heavy Metals in Sediments.

Heavy Metals	$MEC_{Geomean}$ (mg/Kg)	MEC_{Max} (mg/Kg)	PNEC (mg/Kg)	$RQ_{Geomean}$	RQ_{Max}
Cu	76	802	65	1.2	12
Pb	17	253	75	0.22	3.4
Cd	0.2	54	1.5	0.1	36
Cr	33	459	80	0.4	6
Hg	0.01	1.2	0.28	0.04	4.3
Zn	112	673	200	0.6	3
Cd*	0.02	8.3	1.5	0.1	12

* Next highest MEC for Cd

Sources for MEC: PRRP, 1999; BFAR, 1995; EMB-DENR, 1991; Prudente et al., 1994; and Narcise and Jacinto, 1997.
Sources for PNEC: EVS, 1996.

For Hg, Pb and Cr, the RQ_{max} were 4.3, 3.4 and 5.7, respectively, and were calculated for samples taken near Metro Manila (near the port area/Pasig River for Hg and near Bulacan River/Navotas for Pb and Cr). The mean RQ for Hg was less than 1 and less than 0.5 for Pb and Cr.

For Zn, the RQ_{max} was 3.37 and was obtained using data taken near the mouth of Pampanga River. The average RQ for Zn was less than 1.

Two major areas of metal contamination were identified – Bataan and Metro Manila. Several industries, refineries and a power plant are located in Bataan (particularly Limay) while Metro Manila is a highly urbanized and commercial/industrial area where an international port is also located.

Uncertainty Analysis

A preliminary uncertainty analysis for Cr and Pb was conducted using the Monte Carlo simulation, which randomly re-sampled pairs of MECs and PNECs to get a set of RQs. The analysis showed that there is a 26% probability that RQs will exceed one for Cr and a 15% probability that RQs will exceed one for Pb.

Data from several studies were used for this risk assessment. The comparability of these data, however, needs to be verified because different sample pre-treatment methods were employed. The criteria used as PNECs were proposed for another location and their suitability for use in Manila Bay also needs to be reviewed. Grain size is an important factor that influences the concentration of heavy metals in sediments and Manila Bay sediments are fine-grained and muddy and may naturally have higher concentrations of metals than sediments from other locations. Heavy metal data from an offshore or reference site that is texturally and mineralogically representative of the bay or vertical profiles of sediments would be valuable to establish the background concentrations of metals in the bay. These values may not be equivalent to threshold values but these represent pre-contamination concentrations and would give pollution indices for the bay.

Tissue

The data on shellfish tissue were taken from the PRRP Report (1999), BFAR (1995) and Prudente et al. (1997) while the data on fish tissue came from EMB-DENR (1991) and Prudente et al. (1997).

For the LOCs or PNECs, the TDI values were taken from the MPP-EAS (1999b), which used TDI values for non-essential metals (As, Cd, Cr, Hg, Ni and Pb) from the United States Food and Drug Administration (U.S. FDA at http://vm.cfsan.fda.gov), and recommended daily allowances (RDA) for essential metals (Cu, Mn, Zn and Fe) from commercial nutritional supplements. RDAs were used because TDIs for essential metals were not found. In using the RDAs, it should be noted that an RQ greater than one for an essential metal is less likely to cause a risk to human health than an RQ of one for a non-essential metal. The same study found that the difference between the TDI (U.S. FDA) and RDA for Cr was a factor of 4. The average shellfish consumption rate was 19.18 g/person/day while the average fish consumption rate was 92 g/person/day (FNRI, 1987), obtained by taking the sum of the average consumption rates for fresh fish (69.04), dried fish (12.05) and processed fish (10.96).

Fish

The contents of Cd, Cu, Pb, Mn and Hg in fish samples purchased from fishers at ports of Coastal Road have been investigated. The maximum RQ values of all the metals (Table 19) were generally higher than one. The maximum RQ values of copper (10.72 for 1-10 yr old, 2.14 for adult) were found to be the highest among the six metals studied. Copper is an essential metal so it is believed that an RQ greater than one may not represent as much cause for concern as for toxic metals, but a maximum RQ value greater than ten suggests that copper levels in fish may pose a risk to human health.

Table 19. RQs of Heavy Metals in Tissue.

Heavy Metals	$\text{MEC}_{\text{Geomean}}$ (mg/Kg)	MEC_{Max} (mg/Kg)	PNEC (mg/Kg)	$\text{RQ}_{\text{Geomean}}$	RQ_{Max}
Fish					
Cadmium	0.03	0.72	0.6	0.06	1.2
Copper*	3.1	46.6	4.35; 21.73	0.72; 0.14	10.7; 2.14
Lead**	0.117	0.301	0.070; 0.16; 0.27; 0.81	1.8; 0.72; 0.43; 0.14	4.6; 1.8; 1.1; 0.37
Manganese*	15.3	59.8	10.86; 27.16	1.41; 0.560	5.50; 2.20
Mercury	0.11	1.39	0.17	0.61	8.0
Zinc*	41	124	54.32; 162.95	0.76; 0.25	2.28; 0.76
Shellfish					
Cadmium	0.4	2.5	2.87	0.1	0.87
Copper*	20	100	20.86; 104.28	1; 0.2	4.80; 0.96
Lead**	0.4	1.1	0.31; 0.78; 1.30; 3.91	1; 0.5; 0.3; .1	3.5; 1.4; 0.84; 0.28
Zinc*	361	4000	260.69; 782.06	1.39; 0.5	15.34; 5.11
Silver	1	18			

Sources for MEC: PRRP, 1999, EMB-DENR, 1991, BFAR, 1995 and Prudente et al., 1997

Sources for PNEC. Fish consumption rate (92 g/person/day) and shellfish consumption rate (19.18 g/person/day) used for all the age groups were the average for the population (FNRI, 1987). The tolerable daily intakes (TDIs) of the metals were taken from the U.S. FDA (Appendix 4). TDIs were divided by the fish consumption rate to get the levels of concern or PNECs.

* For PNEC, $\text{RQ}_{\text{Geomean}}$ and RQ_{Max}: (1-10 yrs. Old; Adult)

** For PNEC, $\text{RQ}_{\text{Geomean}}$, and RQ_{Max}: (0-6 yrs. Old, 7 –Adults; Pregnant, Adult)

Shellfish

The contents of Cd, Cu, Pb and Zn in shellfish samples (mussels and oysters) from Manila Bay and the mouth of the Pasig River were also investigated. The maximum RQ (Table 19) value of zinc (15.34 for 1-10 yr old, 5.11 for adult) was found to be the highest among the four metals studied. Zinc is also an essential metal, so less importance is attached to RQ values greater than one, but an RQ value greater than ten represents a cause for concern. A high RQ value of 3.52 was obtained for lead in children (0.84 for pregnant women, 1.41 for 7 yr old – adults) and this suggests that lead in shellfish may pose a significant risk to human health. RQ for Ag was not calculated due to a lack of PNEC.

In the calculation of the RQ values given in Table 19, an average fish consumption rate of 92 g/person/day was used for all the age groups in the population. On the other hand, results of a survey of seafood consumption rates in the USA indicate that adults consume 2 – 3 times as much shellfish per day as 2-5 year olds. Applying this to seafood in general and assuming that such an age-specific difference in seafood consumption rate is applicable to the Philippines, maximum RQs for children in relation to various metal contaminants in seafood collected from Manila Bay are calculated and given in Table 20.

Table 20. Maximum RQ of Heavy Metals in Tissue for Children.

Heavy Metals	RQ_{Max} for children*
Fish	
Copper	5.36
Lead	2.31
Zinc	1.14
Manganese	2.75
Shellfish	
Copper	2.40
Lead	1.76
Zinc	7.67

*Assuming that adults consume 2 times as much seafood as 2-5 year old children.

Uncertainty Analysis

In determining risks to human health from heavy metals in seafood tissue from Manila Bay, shellfish tissue would be a better representative sample than fish tissue. The fish samples used in the analysis were collected from the market and it would be difficult to establish if the uptake of heavy metals occurred in Manila Bay.

Another possible source of uncertainty was the use of local average consumption rates in getting the RQs for different age groups. Local consumption rates for different age groups and, if available, separate consumption rates for coastal population, should be used. There was also uncertainty in using the sum of average consumption rates for fresh fish, dried fish and canned fish as average local fish consumption rate because the dried and canned fish consumed by people around the bay do not come exclusively from Manila Bay. Even the fresh fish supply does not all come from the bay.

Uncertainty is also associated with the use of RDAs instead of TDIs for essential metals. This uncertainty should be reduced when information regarding the toxic effects of these metals in humans becomes available. Even the TDIs need to be reviewed since values vary considerably between countries.

Sources

The heavy metals in Manila Bay may come from a variety of sources that range from land-based sources (domestic sewage, run-off, industrial effluents, combustion emissions, mining operation and metallurgical activities) to sea-based sources (port and maritime activities).

Although the heavy metal concentrations in water inside the bay are low and cause no concern, the higher concentrations in the river mouths may show that land-based activities along the river may be contributing significantly to heavy metal load to Manila Bay.

The heavy metal load in the bay is better manifested in the high concentrations in sediments. Heavy metals may be removed from the water column through adsorption and coagulation processes and the ultimate sink is the bottom sediment. A clear illustration of this would be a vertical profile of sediment concentrations showing pre-contamination concentrations and the increase in concentrations over time.

Heavy metals in the water may also be taken in by organisms in the bay through bioaccumulation. Some metals are essential to organisms, some are metabolized and excreted or retained in tissues in less harmful forms, and some are non-essential, but even the essential metals, when uptake or ingestion rate is faster than the rate that these can be processed could be bioconcentrated and become harmful to organisms. The accumulated metals, particularly those that undergo biomagnification, could also pose potential risks to human health through consumption of contaminated seafood.

Identification of sources of heavy metals entering the bay and quantification of the relative contribution of different sources would need data like metal concentrations in the various sources of inputs (rivers, discharge pipes, outfalls, run-off and ships), volumes of inputs, and the partitioning of metals between the dissolved and solid phase and subsequent deposition to the bottom of the bay.

POLYCYCLIC AROMATIC HYDROCARBON (PAHS)

Sediment

The data used in Table 21 came from two sources: the study by Santiago (1997) and the PRRP Report (1999). The data in Santiago (1997) was measured from 19 stations at the western section and 16 stations at the eastern section of the bay in 1996. The PRRP (1999) data were taken from 10 stations across the bay in March and October 1996. The assessment considered only total PAH (TPAH) and the carcinogenic PAHs. The criteria values used were taken from the Hong Kong Interim Sediment Quality Values (EVS, 1996).

Table 21. PAHs in Sediments from Manila Bay.

Agent (PAHs)	$MEC_{Geomean}$ (ug/g)	MEC_{Max} (ug/g)	PNEC (ug/g)	$RQ_{Geomean}$	RQ_{Max}
Santiago (1997)					
Benzo(a) Pyrene	0.01	0.11	0.43	0.03	0.25
Chrysene	0.01	0.12	0.384	0.02	0.30
Dibenzo(a,h) Anthracene	0.002	0.01	0.0634	0.03	0. 16
Total PAH*	0.71	**7.18	4.022	0.43	1.78
PRRP (1999)					
Benzo(a) Pyrene	0.02	0.02	0.43	0.05	0.05
Chrysene	0.02	0.2	0.384	0.06	0.52
Dibenzo(a,h) Anthracene	0.02	0.064	0.0634	0.4	1.0

* Next highest MEC

** TPAH (summation of 18 individual PAH)

Sources of MEC: Santiago, 1997 and PRRP, 1999.

Sources of PNEC: EVS, 1996.

The initial risk assessment of total PAH (TPAH) and carcinogenic PAHs (n = 35) from Santiago (1997) indicated intermediate risk (RQ = 1.78) for TPAH and acceptable risk (RQs < 1) for the carcinogenic PAHs. This study, however, showed that PAH levels in the eastern area, a more commercialized and urbanized area, were higher than the levels in the western side, pointing to the influence of human activities on PAH distribution. The other study (PRRP, 1999) showed two stations in the bay where an RQ of 1.0 and 0.82 were obtained for the carcinogenic PAH dibenzo(a,h) anthracene.

These results show the need for periodic monitoring to keep track of possible increasing trends. PAHs can persist in the marine environment and have been shown to exhibit toxicity and cause tumor and reproductive problems to various marine organisms. Consumption of aquatic organisms contaminated with PAHs could also potentially cause cancer to humans.

Santiago (1997) identified the PAHs in Manila Bay sediments as coming from petrogenic and pyrolytic sources. Petrogenic PAHs may come from oil discharges from ships, refineries and industries and pyrolytic PAHs are derived from combustion processes. These enter the bay through rivers, discharge pipes, outfalls, surface run-off and, to a lesser extent, atmospheric deposition.

OIL & GREASE

Water Column

Oil and grease comprise very complex mixtures of thousands of organic compounds with different behaviors and hence different possible effects on marine life and, ultimately, on human health. Once released into the environment, all of these compounds are subject to continuous and variable change due to biological degradation, photo oxidation, and other processes.

The oil and grease concentrations in water were recorded in 13 different sites in Manila Bay in 1985, 1992 and 1993 (BFAR, 1995). Records showed that there is no significant increase of oil and grease concentration over the period indicated. The criteria value used as PNEC was taken from the DAO 34 (1990) for Class SC waters. Note that this value was reported for the organic fraction extract. Some oil and grease measurements are reported using the water-soluble fraction and should be used with the suitable criteria.

The worst case was measured in a sample taken from Amo, Mariveles in Bataan. The maximum concentration reached as high as 16.55 mg/l and the maximum RQ was 5.5 (Table 22). These observations may be explained by the presence of oil refineries in nearby coastal areas in Mariveles and Limay, Bataan. Mean RQ, was however computed to be low at 0.466 with mean oil and grease concentration in water at 1.40 mg/l.

Table 22. Oil and Grease in Water (PNEC = 3 mg/l).

MECs	Concentration (mg/l)	RQ
Maximum	16.55	6
Minimum	0.01	0.003
Geomean	1.40	0.5

Sources for MEC: BFAR, 1995.
Sources for PNEC: DAO 34,1990 for Class SC waters.

Most of the stations also exceeded the allowance level of 3.0 ppm at least once during the duration of the study.

It should be noted that there is large variability in available critical water concentrations for oil and grease. MPP-EAS (1999b) presents critical values from various studies ranging from 0.001 mg/l to 7 mg/l. This has important implications on the risk assessment results and should be considered in more detail in future assessments.

For the marine environment on a global scale, the primary inputs of oil are believed to occur from land-based sources, in particular refineries, municipal wastes and urban runoff (GESAMP, 1993, cited in MPP-EAS, 1999b). Sea-based sources, like ships and motorized boats, are also contributors, with the level of contribution between land and sea-based sources varying depending on the circumstances of the site. For Manila Bay, a simple model may be developed to determine the likely contribution from these two sources.

Uncertainty Analysis

The $\mathrm{RQ}_{geomean}$ obtained indicates that the levels of oil and grease in the bay were low but the RQ_{max} shows that in specific locations, oil and grease levels may exceed the threshold value, although the RQ_{max} still seemed incompatible with the amounts of oil and grease that are visually observed at near-shore areas especially near the port. Oil that enters the marine environment may be broken down by wave action and dispersed. It may also undergo degradation processes depending on its reaction with sunlight, oxygen, water and organisms. Oil and grease in offshore locations in the bay may not be elevated but measurements in near-shore areas especially near ports, refineries and industries may be higher and should be further assessed.

There was no available data on the different organic constituents of oil and grease in Manila Bay. The complex mixture of organic compounds in oil and grease may have different adverse effects on marine life particularly shellfisheries and benthic organisms. Identification of these various organic constituents will enable the determination of ecotoxicological risks that these present to the ecosystem.

In terms of the PNECs, the order of magnitude differences in critical values from various sources suggest that more consideration and care should be given to the choice of criteria value for oil and grease.

OIL SPILLS

Table 23 shows both spills from ships and industries from 1990 to 1995 and 1999. Data for 1996 to 1998 were not available when the risk assessment was conducted. These may be accidental discharges. Other oil spill incidents may be unrecorded, especially the regular low-volume discharges.

The volumes of oil discharged to the bay in the recorded oil spill incidents (Table 23) were reported in different units (liters, barrels, drums, tonnes) so the units were converted to liters (assumption: oil density = 0.90 g/l) for comparability. For the spills reported in drum units, conversion was not done because the sizes of drums were variable. The volume of other recorded spills were undetermined.

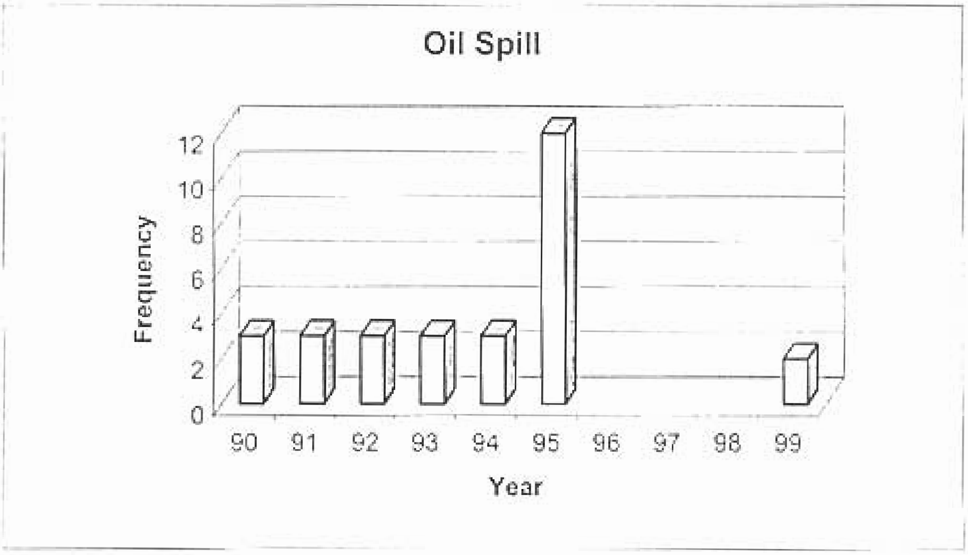
An oil spill is considered a large spill when the volume of oil discharged is greater than 1,500 metric tons (MT). The highest volume of oil spilled in the bay was 747 MT and falls under small spills. Three of the four spills where the volumes of oil discharged were highest were from ships.

The frequencies of oil spill incidents per year are shown in Figure 5. The highest frequency of oil spill incident (12) was in 1995. Figure 6, on the other hand, shows that the highest total volume of oil spilled in the bay was from the two oil spills in 1999. These incidents occurred in the Manila South Harbor and Limay, Bataan. Table 22 shows that the frequency of oil spill occurrences was highest in Metro Manila with 19 incidents recorded, followed by Bataan with 8 incidents, and Cavite and Rizal with one incident each.

The high frequency of oil spills in Metro Manila area can be due to the large number of ships and activities at the North and South Harbors, the presence of an oil terminal, and discharges from industries located along the rivers. Oil spills in Bataan can be due primarily to shipping activities and discharges from industries along the coast.

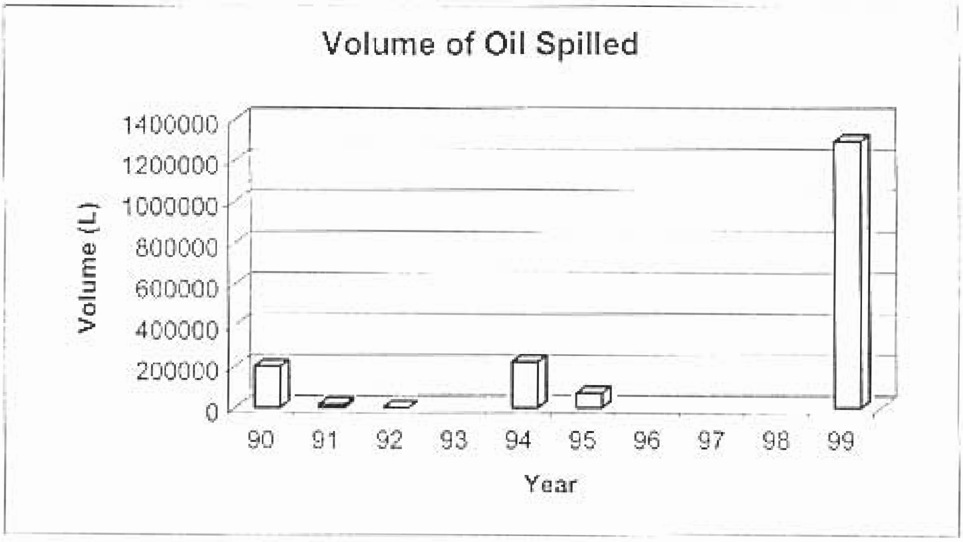
Data on the number of ships entering Manila Bay were not on hand when the assessment was made. Hence, the relationship between the number of oil spills from ships and the number of ships in the bay was not obtained.

Figure 5. Frequency of oil spill occurrences in Manila Bay from 1990-1999.



Source: EMB-DENR, 1996.

Figure 6. Volume of oil spilled in Manila Bay from 1990-99.



Source: EMB-DENR, 1996.

Table 23. List of Oil Spill Incidents in the Manila Bay Area in the 1990s.

Source	Date	Oil Product Spilled	Area Affected	Quantity	
				Reported	Converted to L (assume density=0.9)
MT Fernando J-1	24-Jan-90	Industrial fuel oil	Lamao, Limay, Bataan	200000 L	200000
MV Al Taludi	2-Aug-90	Bunker oil	Manila	10 drums	
Bataan Refinery Corp.	22-Oct-90	Bunker oil	Limay Bataan	5 barrels	1667
MV Carlota	8-Mar-91	Oily water	Mariveles, Bataan	5 drums	
MT Ivy	5-Apr-91	Industrial fuel oil	Lamao Limay, Bataan	20 barrels	6667
MT Nazal-I	20-Dec-91	Auto diesel oil	Pier 8, Manila	10500 L	10500
Sea Oil Petroleum Corp.	2-Sep-92	Bunker oil	Manila	2 drums	
MT Bacolod City	22-Sep-92	Bunker oil	Manila	100L	100
PNOC/PSTC	8-Dec-92	Bunker oil	Pandacan, Manila	2 drums	
Undetermined sources	Feb-93	Bunker oil	Brgy. Marina, Mariveles, Bataan	U. A.	
MT Calumpit	19-Apr-93	Lube oil	Petron Terminal, Pandacan, Manila	20 drums	
MV Nekkei Challenge	19-Jul-93	Grain chaff	South Harbor, Manila	U. A.	
Phil Vinyl Consortium	17-Mar-94		Rosario, Cavite	U. A.	
PBRC	19-Apr-94	Bunker oil	Limay, Bataan	2 drums	
Petro Queen	8-Aug-94	Bunker oil	Manila Bay	670 barrels	223333
Discovery Industrial Corp.	13-Aug-94	Bunker oil	Pasig River	600 L	600
Allied Thread Co.	11-Jan-95	Bunker oil	Marikina River	400 L	400
Rockwell Thermal Plant	17-Jan-95	Bunker fuel	Pasig River	63000 L	63000
MT Agihis (BBCI)	20-Jan-95		Pililla, Rizal	U.A.	
Republic Asahi Glass	3-Mar-95	Bunker/fuel oil	Pinagbuhatan, Pasig City	10L or 2 drums	10
Puyat Steel Corp	3-Mar-95	Bunker/fuel oil	Pasig River, Mandaluyong City	50 to 70 L	50 to 70
Pacific Glass Product	19-Mar-95	Bunker oil	San Juan River	1400 L or 7 drums	1400
PISCOR	20-Mar-95	Diesel oil	Manggahan, Pasig City	20L	20
MT Pandi	12-May-95	Industrial fuel oil	Limay, Bataan	500L	500
Resin Corp	15-Jul-95	Industrial fuel oil	Pasig City	3000 L	3000
Warner Lambert Corp	21-Jul-95	Industrial fuel oil	Pasig City	2000 L	2000
MV Wilcon X	22-Sep-95	IFO/bunker oil	Pier 18, Manila	2 tons or 2000 L	2000
Integral Chemical Corp	14-Oct-95	Diesel oil	Mandaluyong	100 L	100
MT Sea Brothers I	19-Mar-99	Bunker oil	South Harbor, Manila	420 tonnes	466690
MT Mary Anne	1-Jun-99		Limay, Bataan	747 tonnes	830041

Source: PCG as cited in EMB-DENR, 1996; PCG, pers. comm., for 1999 data.

- U.A. – Undetermined Amount

Comparative Risk and Uncertainty Assessment

INTRODUCTION

Comparative risk assessments for the range of agents considered of potential concern for Manila Bay have been carried out separately for water column, sediment, and seafood tissue. The results of these analyses are summarized in Tables 24 - 29. An initial indication of uncertainty in the risk assessments is provided by comparing differences between average and worst-case (i.e., maximum MECs) conditions. In addition, the comparative risk assessments highlight data gaps, both in terms of a lack of MECs and in terms of a lack of criteria.

For all targets, average and maximum MECs for the range of agents are shown. Average MECs were calculated as geometric means since data of this kind often follow a lognormal distribution, and in such cases the geometric mean will provide a less biased measure of the average than will the arithmetic mean. For each contaminant, the criteria used for calculating the risk quotients are shown in column 4 of Tables 9.1, 9.3, and 9.5. These criteria were chosen from those provided in Appendix 4. The last two columns of these tables provide average and maximum risk quotients.

COMPARATIVE ASSESSMENT OF RISKS TO THE ECOLOGY OF MANILA BAY FROM WATER-BORNE SUBSTANCES

From Table 24 it is clear that of all contaminants for which water column data were available only PO_4 and coliforms (both total and fecal) have average RQs exceeding the critical threshold of one. However, in addition to these two contaminants, NO_3, NH_3, DO, oil and grease, TSS, dieldrin and heptachlor have maximum RQs that exceed 1. There were no MECs available for water column concentrations of BOD, COD, PAHs, other pesticides, other organics, or toxic algae. No criteria were available for several of the heavy metals for which MECs were available (i.e., Mn, Fe, Co, U).

Table 25 compares the range of RQs (from average to maximum) across contaminants in order of magnitude bands of RQ. From this table it is clear that, for the water column, risks to the ecosystem of Manila Bay associated with PO_4 and coliforms are priority concerns. For NO_3, NH_3, DO, oil and grease, TSS, dieldrin and heptachlor, the maximum RQs exceeding one indicate localized risks from potential hot spots.

Table 24. Initial Risk Assessment Summary for Water.

Agent	$MEC_{Geomean}$	MEC_{Max}	PNEC	$RQ_{Geomean}$	RQ_{Max}
NO_3-N (mg/L)	0.027	0.387	0.06	0.4	6
PO_4-P (mg/L)	0.029*	0.714	0.0049	5.9	146
NH_3-N (mg/L)	0.003	0.779	0.07	0.04	11
BOD	No Data				
COD	No Data				
DO (mg/L)	5.78	1.0 (min)	5.0	0.87	5.0
Oil and Grease (mg/L)	1.399	16.55	3	0.5	6
Metals (µg/L)					
Copper	0.15	0.2	2.9	0.05	0.07
Lead	0.6	0.8	5.6	0.1	0.1
Zinc	0.14	0.43	55	0.0030	0.010
Silver	0.04	0.05	2.3	0.02	0.02
Cadmium	0.10	0.11	9.3	0.010	0.010
Manganese	0.5	0.6	No data		
Iron	0.43	1.7	No data		
Cobalt	23	24	No data		
Uranium	1.2	1.4	No data		
PAHs	No Data				
Other organics	No Data				
Total Coliform (MPN/100 ml)	13,488	2,400,000	5,000	2.7	480
Fecal Coliform (MPN/100 ml)	7,898	900,000	200	39.5	4500
TSS (mg/L)	23.32	1048	50	0.47	21
Pesticides (µg/l)					
Aldrin		0.0040	No data		
4,4'-DDT		0.0005	0.001		0.5
Dieldrin		0.0060	0.0019		3.16
Heptachlor		0.0210	0.0035		6
Toxic Algae	No data				

Table 25. Comparative Risk Assessment for Water.

Agent	RQ				
	< 1	1-10	10-100	100-1,000	> 1,000
NO_3 (mg/L)	—	—			
PO_4 (mg/L)		—	—	—	
NH_3 (mg/L)	—	—			
BOD	No MECs				
COD	No MECs				
DO (mg/L)	—	—			
Oil and Grease (mg/L)	—	—			
Metals (mg/L)					
Copper	—				
Lead	—				
Zinc	—				
Silver	—				
Cadmium	—				
Manganese	No PNEC				
Iron	No PNEC				
Cobalt	No PNEC				
Uranium	No PNEC				
PAHs	No MECs				
Other organics	No MECs				
Total Coliform (MPN/100 ml)		—	—	—	
Fecal Coliform (MPN/100 ml)			—	—	4500 —
TSS (mg/L)	—	—	—		
Pesticides					
Aldrin	—		No PNEC		
4,4'-DDT	●				
Dieldrin		●			
Heptachlor		●			
Toxic Algae	No MECs				

COMPARATIVE ASSESSMENT OF RISKS TO THE ECOLOGY OF MANILA BAY FROM SEDIMENT-BORNE SUBSTANCES

From Table 26 it is clear that of all contaminants for which sediment data were available, Cu, DDT and its metabolite DDE have average RQs exceeding the critical threshold of one. However, in addition to these contaminants, Cd, Pb, Cr, Zn, Hg, Ni, dibenzo(a,h) anthracene and total PAH have maximum RQs that exceed one. Oil and grease are generally not measured in sediment, and there were also no MECs available for sediment concentrations of other organics and few MECs for most of the pesticides. Criteria values were lacking for several of the heavy metals, particularly Mn, Fe, Co, Mo, and U, as well as for most of the pesticides, TOC and toxic algae.

Table 27 compares the range of RQs (from average to maximum) across sediment-associated contaminants in order of magnitude bands of RQ. From this table it is clear that, for sediment, risks to the ecology of Manila Bay associated with heavy metals, and in particular, Cu, are priority concerns. For Cd, Pb, Cr, Zn, Hg, Ni, dibenzo(a,h) anthracene and total PAH, the maximum RQs exceeding one indicate localized risks at possible hot spot areas.

Table 26. Initial Risk Assessment Summary for Sediment.

Agent	$MEC_{Geomean}$	MEC_{Max}	PNEC	$RQ_{Geomean}$	RQ_{Max}
Oil and Grease	No Data				
Metals (mg/kg)					
Copper	76	802	65	1.2	12
Lead	17	253	75	0.22	3.4
Cadmium	0.2	54	1.5	0.1	36
Chromium	33	459	80	0.4	6
Zinc	112	673	200	0.6	3
Iron	25438.7	151100	No data		
Manganese	723.0	2062	No data		
Mercury	0.01	1.2	0.28	0.04	4.3
Silver	0.6	0.8	1.0	0.6	0.8
Cobalt	12	28	No data		
Nickel	18	86	40	0.44	2.2
Molybdenum	4	4	No data		
Uranium	0.64	1.2	No data		
Carcinogenic PAHs (µg/kg)					
Benzo(a)pyrene	0.01	0.11	0.43	0.03	0.25
Chrysene	0.01	0.12	0.384	0.02	0.30
Dibenzo(a,h) anthracene	0.002	0.064	0.0634	0.03	1.0
Total PAH	0.713	7.176	4.022	0.432	1.784
Other organics	No Data				
Pesticides (µg/g)					
Aldrin	0.0019		1.3672*	0.011	
Alpha-BHC	0.0018	0.00190	No data		
beta-BHC	0.0019		No data		
Delta-BHC	0.0019		No data		
Gamma-BHC	0.0019		No data		
4,4-DD	0.0090		No data		
4,4'-DDE	0.0039		0.0022	1.8	
4,4'-DDT	0.0090		0.0016	5.7	
Dieldrin	0.0039		0.66*	0.006	
Endosulfan I	0.0039		No Data		
Endosulfan II	0.0039		No Data		
Endosulfan Sulphate	0.0090		No Data		
Endrin	0.0039		No Data		
Heptachlor	0.0019		0.068*	0.03	
Heptachlor Epoxide	0.0019				
Methoxychlor	0.0090				
TOC (%)	1.28	2.84	No data		
Toxic Algae Bloom (cysts/ml wet sediment)	38.17	439	No data		

* PNEC was estimated using water quality criteria and sediment-water partition coefficient.

Table 27. Comparative Risk Assessment for Sediment.

Agent	RQ				
	< 1	1-10	10-100	100-1,000	> 1,000
Oil and Grease	No MECs				
Metals mg/kg					
Copper		—	—		
Lead	—	—			
Cadmium	—	—	—		
Chromium	—	—			
Zinc	—	—			
Iron	No PNEC				
Manganese	No PNEC				
Mercury	—	—			
Silver	—				
Cobalt	No PNEC				
Nickel	—	—			
Molybdenum	No PNEC				
Uranium	No PNEC				
Carcinogenic PAHs (ug/kg)					
Benzo(a)pyrene	—				
Chrysene	—				
Dibenzo(a,h) anthracene	—				
Total PAH	—	—			
Other organics	No MECs				
Pesticides (ug/g)					
Aldrin	●				
alpha-BHC	No PNEC				
Beta-BHC	No PNEC				
delta-BHC	No PNEC				
Gamma-BHC	No PNEC				
4,4-DD	No PNEC				
4,4'-DDE		●			
4,4'-DDT		●			
Dieldrin	●				
Endosulfan I	No PNEC				
Endosulfan II	No PNEC				
Endosulfan Sulphate	No PNEC				
Endrin	No PNEC				
Heptachlor	●				
Heptachlor Epoxide	No PNEC				
Methoxychlor	No PNEC				

From Table 28, it is clear that contamination of seafood with fecal coliforms is extremely high, both under average and worst-case conditions. In addition, of the other contaminants for which seafood tissue data were available Cu, Pb, Mn, Zn (particularly in younger age groups of consumers), aldrin and heptachlor have average RQs exceeding the critical threshold of one. All of the metals have maximum RQs that exceed one, as does endosulfan sulfate. Oil and grease are generally not measured in seafood, and there were also no MECs available for tissue concentrations of PAH, other organics or toxic algae. Criteria values were lacking for Ag, as well as for total coliforms, toxic algae, and for many of the pesticides.

Table 29 compares the range of RQs (from average to maximum) for contaminants contained in seafood in order of magnitude bands of RQ. For the heavy metals, the lower limit represents the average RQ for the least sensitive age group (adults) and the higher limit represents the maximum RQ for the most sensitive age group (children). From this table, it is clear that the risk to human health arising from consumption of seafood contaminated with fecal coliforms is serious. Average RQ is equal to 53 and the maximum RQ exceeded 1,000. Other agents of concern for human health are some of the heavy metals, particularly Cu, Zn, Hg, Pb and Mn. Cu, Zn and Mn are essential metals, so RQs in excess of one are probably less serious than for the non-essential metals. For Cu and Zn, however, maximum RQs were greater than 10, signaling potential risks. Of the pesticides, aldrin and heptachlor both signaled cause for concern with RQs exceeding 10.

Table 28. Initial Risk Assessment Summary for Human Health.

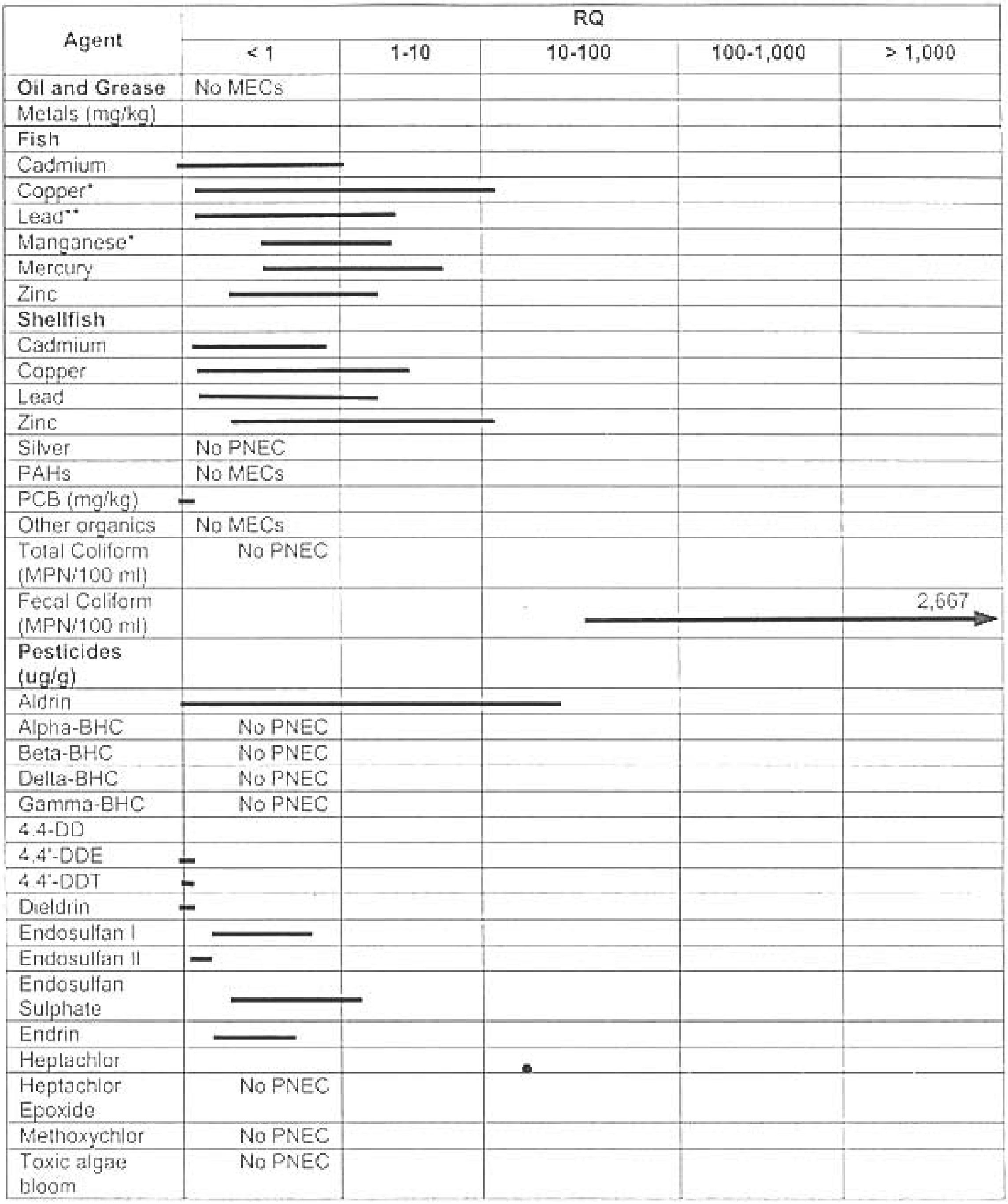
Agent	$MEC_{Geomean}$	MEC_{Max}	PNEC	$RQ_{Geomean}$	RQ_{Max}
Oil and Grease	No Data				
Metals (mg/kg)					
Fish:					
Cadmium	0.03	0.72	0.6	0.06	1.2
Copper*	3.1	46.6	4.35; 21.73	0.72; 0.14	10.7; 2.14
Lead**	0.117	0.301	0.070; 0.16; 0.27; 0.81	1.8; 0.72; 0.43; 0.14	4.6; 1.8; 1.1; 0.37
Manganese*	15.3	59.8	10.86; 27.16	1.41; 0.560	5.50; 2.20
Mercury	0.11	1.39	0.17	0.61	8.0
Zinc*	41	124	54.32; 162.95	0.76; 0.25	2.28; 0.760
Shellfish:					
Cadmium	0.4	2.5	2.87	0.1	0.87
Copper	20	100	20.86; 104.28	1; 0.2	4.80; 0.96
Lead**	0.4	1.1	0.31; 0.78; 1.30; 3.91	1.27; 0.51; 0.31; 0.10	3.5; 1.4; 0.84; 0.28
Zinc*	361	4000	260.69; 782.06	1.39; 0.46	15; 5
Silver	0.68	18	No data		
PAHs	No Data				
PCBs (mg/kg)	0.05	0.05	14	0.07	0.07
Other organics	No Data				
Total Coliform (MPN)	56,439	$16 \times 10^{\text{[illegible]}}$	No data		
Fecal Coliform (MPN)	15,752	800,000	300	53	2667
Pesticides (ug/g)					
Shellfish:					
Aldrin	0.00659	0.00900	0.24	0.027	0.038
Alpha-BHC	0.00659	0.00900	No data		
Beta-BHC	0.00659	0.00900	No data		
delta-BHC	0.00659	0.00900	No data		
Gamma-BHC	0.02115	0.07100	No data		
4.4-DD	0.06900		No data		
4.4'-DDE	0.00756	0.01900	4.0	0.002	0.005
4.4'-DDT	0.08283	0.69000	4.0	0.020	0.17
Dieldrin	0.01900		0.24		0.079
Endosulfan I	0.03663	0.17800	0.24	0.15	0.74
Endosulfan II	0.02704	0.06800	0.24	0.11	0.28
Endosulfan Sulphate	0.09950	0.30600	0.24	0.42	1.2
Endrin	0.05747	0.15200	0.24	0.24	0.63
Heptachlor	0.02256	0.05700	No data		
Heptachlor Epoxide	0.01535	0.13000	No data		
Methoxychlor	0.05900		No data		
Fish:					
Aldrin	1.20		0.05	24	
Alpha-BHC	4.11		No data		
Heptachlor	3.25		0.05	65	
Toxic algae bloom	No data		40 ug/100 g shellfish meat or 200 MU/100 g shellfish meat		

* For PNEC, $RQ_{Geomean}$, RQ_{Max}: (1-10 yrs. Old; Adult)

** For PNEC, $RQ_{Geomean}$, RQ_{Max} (0-6 yrs. Old; 7 –Adults; Pregnant, Adult)

Note: The fish consumption rate (92 g/person/day) and shellfish consumption rate (20 g/person/day) used for all the age groups was the average for the population.

Table 29. Comparative Risk Assessment for Human Health.



Agent	RQ				
	< 1	1-10	10-100	100-1,000	> 1,000
Oil and Grease	No MECs				
Metals (mg/kg)					
Fish					
Cadmium					
Copper*					
Lead**					
Manganese*					
Mercury					
Zinc					
Shellfish					
Cadmium					
Copper					
Lead					
Zinc					
Silver	No PNEC				
PAHs	No MECs				
PCB (mg/kg)					
Other organics	No MECs				
Total Coliform (MPN/100 ml)	No PNEC				
Fecal Coliform (MPN/100 ml)					2,667
Pesticides (ug/g)					
Aldrin					
Alpha-BHC	No PNEC				
Beta-BHC	No PNEC				
Delta-BHC	No PNEC				
Gamma-BHC	No PNEC				
4,4-DD					
4,4'-DDE					
4,4'-DDT					
Dieldrin					
Endosulfan I					
Endosulfan II					
Endosulfan Sulphate					
Endrin					
Heptachlor					
Heptachlor Epoxide	No PNEC				
Methoxychlor	No PNEC				
Toxic algae bloom	No PNEC				

Conclusions, Data Gaps and Uncertainties

RETROSPECTIVE RISK ASSESSMENT

For fisheries and shellfisheries, the retrospective risk assessment particularly draws attention to overfishing/overcollection as being the important agent in the decline of these resources. Other factors like pollution and destruction of habitats have also contributed to the decline.

There is a need to determine the extent and level of overfishing for these particular resources by comparing actual yield with the maximum sustainable yield. Cost-benefit analysis of fishing activities in the bay can be done through the maximum efficiency yield which compares the aggregate and marginal costs of fishing with the aggregate and marginal benefits. The suitability of using the MSY for assessing fisheries exploitation in the bay should also be further evaluated. Other approaches in determining the extent of fisheries exploitation like the dynamic MEY and depreciation values should be considered as well. Dynamic MEY uses a discounting factor to take into account changes in values across time, i.e., the state where the present value of marginal cost equals the present value of marginal benefits. Depreciation value indicates that the rate of change in the asset value of the stock is negative.

For shellfisheries, more information is required in making a clear distinction between decline in shellfisheries from culture farms and from the wild, and in attributing causes of decline. Further work also needs to be done to distinguish the contribution of low market demand due to red tide to the decline in production values. In addition, for shellfisheries, given the observed coliform contamination in the tissues, immediate actions are deemed necessary. The disappearance and/or near absence of other species, like the greater lizard fish (*Saurida tumbil*), locally known as kalaso, and the windowpane oyster (*Placuna placenta*), locally known as kapis, should also be mitigated.

There is evidence for a definite decline in the abundance and biomass of benthic fauna with a shift in community structure from a bivalve-dominated toward a polychaete-dominated system. The systematic approach of the initial risk assessment confirms the view that oxygen depletion is likely to be the major contributory cause. Other factors might also be implicated, but those for which exposure data are available appear to be unimportant. There is nevertheless the possibility that substances for which no measurements are currently available could be contributing to declines in the benthos, e.g., contaminants, such as substances used in antifouling paints on ships, fishing gear and in aquaculture.

Often, emphasis is placed on phytoplankton as indicators of ecological problems (e.g. conditions leading to toxic blooms or as signals of eutrophication). Phytoplankton, however, are also clearly an important resource for supporting higher trophic levels in the bay. The retrospective risk assessment should therefore be in terms of both risks from and risks to this resource. The retrospective analysis undertaken also indicates that several of the agents might have adverse effects on phytoplankton abundance and community structure, and this may have an impact on primary production with knock-on effects for fisheries and benthos. An increasing trend, however, has been observed in chlorophyll-a measurements, indicating low risk for phytoplankton with respect to primary productivity.

Consideration of risks from toxic blooms is discussed in the prospective risk assessment. The prospective risk assessment also indicates that nutrient levels are such as to cause general blooms. Such blooms will have consequences for oxygen levels with implications for fisheries and benthos.

The mangrove areas within Manila Bay have obviously declined over the past decades. The retrospective risk assessment implicates a combination of factors with physical removal for reclamation, land conversion, and collection as being primary agents. Chemical contamination and physical disruption of the habitat by sedimentation and solid wastes might also be contributing factors. Another factor that contributed to the decline in mangroves in certain areas is pest infestation, which may be one manifestation of an ecosystem under stress, allowing pests to thrive.

For coral reefs, comparative historical information is sparse to assess the extent of decline, but unpublished accounts and the current poor state of the reefs indicate that there might have been a decline. Physical destruction from collection activities and improper fishing practices as well as smothering of the corals from coastal siltation might have been the leading causes for the decline. The levels of some chemical contaminants in the water column and sediments might have been contributory factors.

For seagrasses and seaweeds, there is uncertainty about the extent of decline of these resources within Manila Bay since comparative historical information is sparse. The retrospective risk assessments nevertheless suggest that impacts are possible from various factors such as sedimentation, pollution, and destructive fishing practices.

For mudflats, sand flats, beach areas and rocky shores, retrospective risk assessment could not be carried out due to lack of available information.

PROSPECTIVE RISK ASSESSMENT

The analysis shows that for human health, the major risks both from bathing and from seafood consumption arise from bacterial sewage contamination. Additional risks associated with consumption of seafood contaminated with some heavy metals and certain pesticides also signal cause for concern.

From an ecological point of view the highest RQ values were obtained for nutrients, especially phosphate, in the water column and copper in the sediments. RQs for dissolved oxygen in the water column were in a lower band, but note should be taken here of the fact that the RQ range for DO cannot go beyond a certain limit. The impact of DO is likely to be of an acute form, which will depend upon exposure times. Thus anoxic conditions over short periods may have considerable impact on fauna, particularly benthic animals. Levels of TSS, oil and grease and certain pesticides in the water column and Cd, Cr, Hg, Zn, Pb, Ni, some pesticides, total PAH and dibenzo (a,h) anthracene in the sediments were also above critical values in some areas.

The initial risk assessment suggests that metals in the water column and PCBs in shellfish tissue are associated with low/acceptable risk although results for heavy metals need to be verified. There are very few studies on heavy metals in seawater and no new data may be available, so monitoring for heavy metals in seawater may be necessary.

DATA GAPS

Retrospective risk assessment was not carried out for some resources and habitats due to lack of comparative information. The initial risk assessment also identified other data that would be necessary as starting points for fisheries/shellfisheries management in the bay.

1) For economically important resources such as fish and shellfish, there is a need to acquire survey data, preferably from more recent surveys. Production data, preferably on a per species classification, including corresponding economic information, i.e. market and non-market values, would be necessary for the development of a model describing fish and shellfish population dynamics and hence indicate sustainable and efficiency yields. For shellfish, data on tissue quality and information on the possible health implications of bacterial/coliform contamination, as well as, red tide occurrences, should be gathered.

2) For seagrass, seaweeds, coral reefs, mudflats, sand flats and beaches, and rocky shores, there were no available time series and spatial distribution data. There were also no information on access and use of mudflats, sand flats and beaches, and rocky shores.

3) There were no available data on phytoplankton composition, abundance and biomass.

Prospective risk assessment was not carried out for some parameters due to lack of measured environmental concentrations or lack of threshold values. The following potentially important data gaps were identified in the initial risk assessment and would need further effort in the refined risk assessment.

1) For water column, there were no data on BOD/COD in the bay, PAHs and other organic chemicals and limited information on heavy metals, pesticides and oil and grease.

2) For sediments there were no data on other organic chemicals, particularly organotins, and yet levels of shipping would suggest that these are potentially important contaminants derived from anti-fouling paints. And generally, there was a lack of appropriate criteria for pesticides and for TOC.

3) In terms of human health risks, there was a lack of data for some pesticides and heavy metals in fish. There were no data for pesticides, heavy metals and coliform in shellfish tissue as well as coliform in water from the western section of the bay. There were no data on PAHs and TBT in tissue. There were also few TDIs for pesticides, no TDIs for essential metals, and no criteria for total coliforms in shellfish and fish tissue.

On the basis of past experience, the risks posed by toxic algal blooms are considerable and obviously important for human health. There have been no reports of toxic blooms during the past two years, but this cannot preclude further occurrences in the future. Plankton data in the water column, cyst counts in sediments and PSP levels in shellfish are important indicators of this phenomenon.

Another source of risk that has been addressed in a preliminary way comes from accidental spills from shipping. Here, there ought to be concern about likelihood of occurrence of accident and the consequent likely exposure. These are functions of the rate of ship movements into and out of the bay, quantity and quality of cargo, experience of crew, age of vessel, and various other factors. The only data available are the number of ships having accidents per year and the average volumes of spills from them. Effort was simply limited to the computation of the likely average release of oil into the bay per annum, with the assumption that the past conditions in all the aforementioned factors do not change for the future (remain constant). Data on the abovementioned factors should be gathered and used as inputs to a model that will predict the likelihood of accidental oil spills and the likely impacts on the bay.

Aside from accidental oil spills from shipping, operational discharges should also be assessed. This also goes for refineries and industries where controlled and uncontrolled oil discharges occur. Although accidental oil spills draw attention due to the volume of oil released into the environment over a short period, oil coming from daily operational activities from shipping and industrial activities also contribute significantly to the oil and grease levels in the marine environment.

Recommendations and Proposed Actions

RECOMMENDATIONS AND PROPOSED ACTIONS FOR REFINING THE RISK ASSESSMENT

Fisheries

In order to understand and hence appropriately manage fishing activities it will be necessary to develop models that describe the dynamics of the fish and shellfish populations and hence indicate sustainable and efficiency yields. A comparison with these yields will give a more objective indication of the level of overfishing and the extent to which other factors might be contributing to declines in stocks. For risk management, partial bans on fishing activity have been used in some areas to assess empirically how reductions in harvesting may lead to recovery of stocks. The effectiveness of such bans is still being evaluated.

Phytoplankton

For phytoplankton, it would be useful to systematically assess spatial and temporal changes in phytoplankton biomass, production and species composition with the development and establishment of a monitoring program. These should be designed to give further insight into the interactions between environmental agents and population dynamics of the phytoplankton. It would appear that much effort is being put into consideration of the relationship between environmental conditions and phytoplankton blooms, with emphasis on phytoplankton as indicators of ecological problems, but possibly, emphasis also needs to be directed toward the extent to which toxic contaminants might impair primary production – this being the basis of marine food chains. A close working relationship needs to be developed between the Manila Bay team and the various research groups that are working in this area.

Soft-bottoms

Deteriorating environmental conditions, particularly manifested in the decline in dissolved oxygen, appears to be a major factor in the decline of the benthic community. There is a need to further ascertain the degree with which almost or practically anoxic conditions have adversely affected benthic organisms. The decline in dissolved oxygen indicates an increased oxygen demand on the bay for the decomposition of organic load. To prevent further reduction of dissolved oxygen, risk management should address the need to prevent excessive inputs of organic materials into the bay. It is also possible that exposure to other chemicals might be contributing to the decline in the benthos. There is, therefore, also a need to determine the extent to which other possible agents like organotins and other chemicals, and fishing activities that disturb the bottom sediments, have contributed to the decline in benthos. Organotins, particularly, are known to have disruptive effects on hormones of marine organisms, especially mollusks, leading to sterility and reduction in reproductive success.

Coliform

The human health risk presented by coliform in the water column and biota had been adequately established in the initial risk assessment. The following recommendations are for the risk management phase of the project.

An urgent need is for the development of management plans for controlling food supplies from critically contaminated sites. It will also be important to put in place a more systematic assessment of tissue contamination in fish foods: for example this could involve routine assessment of landings at the main fishing port(s).

There is also a need for a routine monitoring of coliform levels in bathing areas and for responsible agencies or local government units to sanction the owners of resorts that present a clear risk to the public. An intensive information and education campaign should also be conducted to inform the public of the adverse effects of bathing in, and more importantly, ingesting seafood from, contaminated waters. There is also a need to perform morbidity and mortality statistics analyses in areas surrounding the bay to determine the extent to which coliform contamination has affected human health.

More importantly, there is a need to address the source of coliform contamination. The high bacterial load may be attributed mainly to sewage generated from households and commercial, agricultural, institutional and industrial establishments that discharge directly to the bay or to the drainage and river systems which eventually enter the bay. There is a need to fast track sewage collection and treatment programs in watershed areas. Direct discharges of domestic, industrial and agricultural waste, including septic or sludge disposal to Manila Bay and its tributaries should be stopped. A control program for indirect discharges, such as urban and agricultural run-off to Manila Bay and its tributaries should also be implemented.

Cost-benefit analysis should be performed to identify the most appropriate interventions. Models should be used to identify and evaluate benefits and costs of the various interventions.

Nutrients

From an ecological point of view, more information will be needed for nutrients in terms of spatial and temporal distributions, but in particular, identification of likely sources from agriculture and domestic activities is required. N:P ratios in the bay may indicate trends in nutrient loading and should also be determined. Predictive models might be developed here to identify relative importance of sources and hence draw attention to appropriate management.

Heavy Metals

For heavy metals, particular attention needs to be given to spatial distributions of Cu in sediments and Cu, Zn, Hg and Pb in seafood tissue, again with consideration being given to possible sources. Industrial activities are likely to be implicated here, and it may be necessary to develop models that give some predicted environmental concentrations so that management programs can be developed.

With regard to human health risks from consumption of seafood contaminated with heavy metals, there appears to be a considerable amount of information on human consumption patterns but this should be brought up to date with particular attention being focused on age differences. Uncertainties in the TDIs and in the use of RDAs for essential metals should also be reduced as more information become available. The extent to which human health has been affected by the levels of metals in seafood should also be determined by analyzing morbidity and mortality statistics in areas surrounding the bay.

As part of an overall environmental management of the bay, an integrated monitoring program to conduct routine monitoring of heavy metals in seafood, particularly shellfish tissue, should be developed.

Dissolved Oxygen

Reduction of dissolved oxygen in the water column appears to be a particularly important cause of ecological impact. However, a more refined analysis will be required to describe temporal variation in concentrations, especially in deep waters, and to relate this to likely impacts on key ecological systems. The likely impacts of phytoplankton blooms on DO levels, extent of area affected and duration of exposure of organisms to low DO should be assessed. A model for organic loading and potential impacts on DO levels should also be developed.

Pesticides

More information will be needed for pesticides in water and tissue, with attention being given to likely sources. Extensive agricultural activities in regions around the bay are likely to be the most significant contributors. Lack of data in terms of measured concentrations and threshold values may require the conduct of rapid appraisal using data on pesticide releases and ecotoxicological properties to be able to estimate environmental risk.

Oil and Grease

More recent information on oil and grease especially in near-shore areas would be necessary. The major organic constituents of oil and grease in the bay should also be identified to enable the determination of ecotoxicological risks that these present to the ecosystem. Identification of possible sources would be supported by information on estimated average discharges from households and commercial establishments or from municipalities and operational discharges and accidental spills from industrial and shipping activities. A simple model may be developed to determine the likely contribution from land-based and sea-based sources.

The complex mixture of organic compounds in oil and grease may have different adverse effects on marine life particularly shellfisheries and benthic organisms. It is recommended that the major organic constituents of oil and grease in the bay be identified to enable the determination of ecotoxicological risks that these present to the ecosystem. It is also recommended that more information be gathered on the sensitivity of the resources and habitats in the bay to oil and grease.

Critical water concentrations from various sources could differ by orders of magnitude. This would mean that RQs could be even greater than what were obtained in this study, and shows that more consideration and care should be given to the choice of criteria values.

Total Suspended Solids

For TSS, there is a need to quantify contributions from various sources to be able to prioritize management requirements. Spatial and temporal variability should be assessed and relative contributions from domestic, industrial, agricultural, aquaculture, reclamation and dredging activities should be estimated. In harmony with a hydrodynamic model of the bay, models showing the fate of suspended solids in the bay and the potential impacts on habitats and resources should be utilized.

Data Gaps and Sources of Uncertainty

There will be an important need to fill data gaps on BOD/COD, PAH and other organic substances. Additional data on heavy metals and pesticides in the water column, coliform in water and tissue and heavy metals and pesticides in tissue from the western section of the bay would be necessary to verify the assessments that have been made using the limited data available.

In general, further consideration needs to be given to all criteria values, especially those concerned with pesticides in sediments.

Attention will need to be given to the possible occurrence of organotins within the bay. A monitoring program involving a systematic sampling design from ports out into open waters should be required. Investigations on shell deformities and/or imposex (imposition of male characters on female gonad formation) in oysters should also be conducted.

Predicting the likelihood of toxic algal blooms is something of a special case. The RQ analysis that has been the basis of the initial risk assessment is not suited for addressing this issue. In order to predict likely population explosions of algal cells, it is necessary to have a detailed understanding of their population dynamics and the way environmental factors interact with them. These kinds of models are currently under development and should be taken into account in the development of the refined risk assessment program. In view of the central importance of these models in the refined risk assessment, it is believed that these should be given a high priority and close coordination with the research groups working on these models should be developed.

The occurrences of other phytoplankton blooms and the possible ecological effects should also be considered. The high nutrient, especially phosphate, concentrations in the bay may directly support the initiation and/or proliferation of these phytoplankton blooms. The effect of the increase in primary production on the dissolved oxygen levels in the sub-surface water column should also be investigated.

Chlorophyll-a concentrations were not taken up in the initial risk assessment. This is an index of plankton biomass and may indicate when phytoplankton should be considered as an agent or a resource in the bay and should be included in the refined risk assessment.

Coastal erosion and sedimentation have been discussed to some extent as agents in the decline of some resources and habitats and as contributors to suspended solids in the water column, but these areas merit more attention in the refined risk assessment. These processes can change the character of the coastline, contribute to habitat destruction and changes in community structure, and pose risks to human and economic activities along the coast. These are caused both by natural processes and human activities in the coast as well as in upland areas. The natural factors are beyond human control but the human activities that enhance the destruction of natural processes can be identified and controlled. The assessment should include determination of the extent of erosion and sedimentation in the bay, identification of likely causes, and assessment of risks to the ecosystem, community and economy.

The RQ approach has not been suitable for dealing with risks posed by solid wastes, yet these are an obvious problem in the bay (and the surrounding river systems) for shipping, human health, ecological systems, and aesthetics. To refine assessment of the risks posed by solid waste will require increased understanding about sources, distribution and impacts. For example, there may be ecological problems arising from physical disruption of habitats caused by the accumulation of plastics and other solids. This could be particularly important for systems like the mangrove forests.

In order to develop better predictive models of likely impacts from shipping accidents, it will be necessary to develop models incorporating all of the features noted in the above section that are likely to influence the probability of accidents and the consequent likely impact in terms of Manila Bay resources. On the latter it would be useful to develop models of most likely areas in which accidents might occur and to consider their proximity to natural resources. This will be important in developing emergency procedures.

To refine all the risk assessments there will be a general requirement to develop a robust and user-friendly model of hydrodynamics for the bay. This will enable the more precise assessment of relative contributions of sources of contaminants to conditions within the bay, especially with regard to partitioning between river and watersheds and coastal activities. The model should also provide insight into temporal and spatial variations in exposure concentrations that will be important to further the understanding of the relative risks posed by the various contaminants.

It is also important to recognize that the initial risk assessment has been based largely on worst-case and average scenarios. For a number of the agents, further insight will come from making the spatial and temporal variations clear and explicit. This will also enable the distinction between localized and bay-wide conditions and the corresponding risk assessment results.

Other possible sources of uncertainties in the results of the initial risk assessment have also been identified. These are mostly associated with the quality, comparability and adequacy of the measured concentrations and the suitability of the threshold concentrations employed. PNECs have been estimated from values derived from various sources (see Appendix 4), and it will be important to define those ones of particular relevance for Manila Bay. It should then be possible to further clarify risk assessments through the application of quantitative uncertainty analyses as specified in the risk assessment manual. This should be particularly important for DO, TSS, nitrate, certain metals and pesticides in shellfish and sediments, and human health risks from seafood consumption in general.

The initial risk assessment has focused entirely on a consideration of risks to human health and ecological systems from conditions in the bay that are influenced by human activities. The consequent impacts therefore derive from socioeconomic activities and have implications for the economy. Refinement of the risk assessment should make these links more explicit in the form of qualitative risk pathways and more quantitative socioeconomic analyses.

SUMMARY OF MAJOR AREAS OF CONCERN FROM THE PROSPECTIVE RISK ASSESSMENT

From the comparative risk assessment tables (Tables 9.2, 9.4 and 9.6), areas of concern were identified and prioritized in the order of the levels of concern as indicated by the RQs.

For ecological impacts from levels of contaminants in the water column and sediments:

Water column:	Nutrients (especially PO_4) > DO/BOD/COD > TSS > pesticides > oil and grease
Sediment:	Heavy metals (especially Cu) > pesticides > PAHs

For human health impacts:

Water column:	Coliform

Tissue: Coliform > heavy metals > pesticides

The parameters that are not included in the priority list have either been considered of low priority due to low measured concentrations or not been assessed due to lack of information on measured concentrations or threshold values. Heavy metals in the water column and PCBs in tissue fall under the first category although further verification depending on availability of data would be necessary for heavy metals.

Risk assessment has not been carried out for PAHs, PCBs and TBT in the water column due to lack of measured concentrations and TOC in sediments due to lack of threshold value although low levels of PCBs in tissue indicate that these might not be priority contaminants in the water column.

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Glossary

Accuracy. The degree to which a measurement reflects the true value of a variable.

Adverse ecological effects. Changes that are considered undesirable because they alter valued structural or functional characteristics of ecosystems or their components. An evaluation of adversity may consider the type, intensity, and scale of the effect as well as the potential for recovery.

Agent. Any physical, chemical, or biological entity that can induce an adverse response (synonymous with stressor).

Assessment endpoint. An explicit expression of the environmental value that is to be protected, operationally defined by an ecological entity and its attributes.

Attribute. A quality or characteristic of an ecological entity. An attribute is one component of an assessment endpoint.

Benthic community. The community of organisms dwelling at the bottom of a pond, river, lake, or ocean.

Bioaccumulation. General term describing a process by which chemicals are taken up by an organism either directly from exposure to a contaminated medium or by consumption of food containing the chemical.

Bioconcentration. A process by which there is a net accumulation of a chemical directly from an exposure medium into an organism.

Biomagnification. Result of the process of bioaccumulation and biotransfer by which tissue concentrations of chemicals in organisms at one trophic level exceed tissue concentrations in organisms at the next lower trophic level in a food chain.

Contaminant of concern. A substance detected at a hazardous waste site that has the potential to affect ecological receptors adversely due to its concentration, distribution, and mode of toxicity.

Community. An assemblage of populations of different species within a specified location and time.

Comparative risk assessment. A process that generally uses a professional judgment approach to evaluate the relative magnitude of effects and set priorities among a wide range of environmental problems.

Concentration. The relative amount of a substance in an environmental medium, expressed by relative mass (e.g., mg/kg), volume (ml/L), or number of units (e.g., parts per million).

Correlation. An estimate of the degree to which two sets of variables vary together, with no distinction between dependent and independent variables.

Degradation. Conversion of an organic compound to one containing a smaller number of carbon atoms.

Disturbance. Any event or series of events that disrupts ecosystem, community, or population structure and changes resources, substrate availability, or the physical environment.

Ecological component. Any part of an ecosystem, including individuals, populations, communities, and the ecosystem itself.

Ecological entity. A general term that may refer to a species, a group of species, an ecosystem function or characteristic, or a specific habitat. An ecological entity is one component of an assessment endpoint.

Ecosystem. The biotic community and abiotic environment within a specified location and time, including the chemical, physical, and biological relationships among the biotic and abiotic components.

Ecotoxicology. The study of toxic effects on nonhuman organisms, populations, or communities.

Effects assessment. The component of a risk analysis concerned with quantifying the manner in which the frequency and intensity of effects increase with increasing exposure to substance.

Environmental risk assessment. The likelihood that an environmental condition caused by human activity will cause harm to a target. It involves estimating the likelihood of harm being done to human health and/or ecosystems through factors emanating from human activities that reach their natural targets via the natural environment.

Exposure. Co-occurrence of or contact between a stressor and an ecological component. The contact reaction between a chemical and a biological system, or organism.

Exposure assessment. The component of a risk analysis that estimates the emissions, pathways and rates of movement of a chemical in the environment, and its transformation or degradation, in order to estimate the concentrations/doses to which the system of interest may be exposed.

Fate. Disposition of a material in various environmental compartments (e.g., soil or sediment, water, air, biota) as a result of transport, transformation, and degradation.

Food-chain transfer. A process by which substances in the tissues of lower-trophic-level organisms are transferred to the higher-trophic-level organisms that feed on them.

Habitat. Place where a plant or animal lives, often characterized by a dominant plant form and physical characteristics.

Hazard. The likelihood that a substance will cause an injury or adverse effect under specified conditions.

Hazard assessment. Comparison of the intrinsic ability of a substance to cause harm (i.e., to have adverse effects for humans or the environment) with its expected environmental concentration, often a comparison of PEC and PNEC. Sometimes referred to as risk assessment.

Hazard identification. Identification of the adverse effects that a substance has an inherent capacity to cause, or in certain cases, the assessment of a particular effect. It includes the identification of the target populations and conditions of exposure.

Ingestion rate. The rate at which an organism consumes food, water, or other materials (e.g., soil, sediment). Ingestion rate usually is expressed in terms of unit of mass or volume per unit of time (e.g., kg/day, L/day).

Lowest-observable-adverse-effect level (LOAEL). The lowest level of a stressor evaluated in a toxicity test or biological field survey that has a statistically significant adverse effect on the exposed organisms compared with unexposed organisms in a control or reference site.

LC_{50}. A statistically or graphically estimated concentration that is expected to be lethal to 50% of a group of organisms under specified conditions.

Measurement endpoint. A measurable ecological characteristic that is related to the valued characteristic chosen as the assessment endpoint. Measurement endpoints often are expressed as the statistical or arithmetic summaries of the observations that make up the measurement. Measurement endpoints can include measures of effect and measures of exposure.

Population. An aggregate of individuals of a species within a specified location in space and time.

Precision. A measure of the closeness of agreement among individual measurements.

Predicted or estimated environmental concentration (EC). The concentration of a material predicted/estimated as being likely to occur in environmental media to which organisms are exposed.

Primary effect. An effect where the stressor acts on the ecological component of interest itself, not through effects on other components of the ecosystem (synonymous with direct effect; compare with definition for secondary effect).

Prospective risk assessment. An evaluation of the future risks of a stressor(s) not yet released into the environment or of future conditions resulting from an existing stressor(s).

Reference site. A relatively uncontaminated site used for comparison to contaminated sites in environmental monitoring studies, often incorrectly referred to as a control.

Representative samples. Serving as a typical or characteristic sample; should provide analytical results that correspond with actual environmental quality or the condition experienced by the contaminant receptor.

Retrospective risk assessment. An evaluation of the causal linkages between observed ecological effects and stressor(s) in the environment.

Risk. The probability of an adverse effect on humans or the environment resulting from a given exposure to a substance. It is usually expressed as the probability of an adverse effect occurring, e.g., the expected ratio between the number of individuals that would experience an adverse effect in a given time and the total number of individuals exposed to the risk factor.

Risk assessment. A process which entails some or all of the following elements: hazard identification, effects assessment, exposure assessment and risk characterization. It is the identification and quantification of the risk resulting from a specific use of occurrence of a chemical including the determination of exposure/dose-response relationships and the identification of target populations. It may range from largely qualitative (for situations in which data are limited) to fully quantitative (when enough information is available so the probabilities can be calculated).

Risk characterization. The step in the risk assessment process where the results of the exposure assessment (e.g., PEC, daily intake) and the effects assessment (e.g., PNEC, NOAEL) are compared. If possible, an uncertainty analysis is carried out, which, if it results in a quantifiable overall uncertainty, produces an estimation of the risk.

Risk classification. The weighting of risks in order to decide whether risk reduction is required. It includes the study of risk perception and the balancing of perceived risks and perceived benefits.

Risk Pathways (Exposure Pathways). A diagrammatic representation of the course that all agents take from a source to exposed organisms (target) (Modified from, EPA). In the diagram, each exposure pathway includes a source or release from a source, an exposure point, and an exposure route. If the exposure point differs from the source, transport/exposure media (i.e., air, water) also are included. For the particular use of the report, the major categories found in the diagram include economic/social drivers (sources), hazards, resources and habitats (targets), and the effects on the economy. It may also sometimes be referred to as the *conceptual model* that describes ecosystem or ecosystem components potentially at risk, and the relationships between measurement and assessment endpoints and exposure scenarios.

Sample. Fraction of a material tested or analyzed; a selection or collection from a larger collection.

Secondary effect. An effect where the stressor acts on supporting components of the ecosystem, which in turn have an effect on the ecological component of interest (synonymous with indirect effects; compare with definition for primary effect).

Sediment. Particulate material lying below water.

Source. An entity or action that releases to the environment or imposes on the environment a chemical, physical, or biological stressor or stressors.

Species. A group of organisms that actually or potentially interbreed and are reproductively isolated from all other such groups; a taxonomic grouping of morphologically similar individuals; the category below genus.

Stressor. Any physical, chemical, or biological entity that can induce an adverse response (synonymous with agent).

Swept-area method. A holistic method of estimating the absolute measure of biomass which makes use of the so-called "swept area" or "effective path swept" of a trawl (equivalent to the length of the path times the width of the trawl). The total biomass, usually expressed in mass or weight per area or simply in unit mass or weight, for a certain area, A, is computed utilizing the formula, $B = \frac{\overline{(Cw/a)} * A}{X1}$, where $\overline{(Cw/a)}$ is mean catch per unit area (for all hauls) and X1, the fraction of the biomass in the effective path swept by the trawl which is actually retained in the gear (usually its values chosen from the range of 0.5 to 1.0, with 0.5 being used mostly in survey work conducted in southeast Asia).

Threshold concentration. A concentration above which some effect (or response) will be produced and below which it will not.

Tolerable daily intake (TDI). Regulatory value equivalent to the acceptable daily intake established relevant regulatory bodies and agencies, e.g. US Food and Drug

Administration, World Health Organization, and the European Commission Scientific Committee on Food. It is expressed in mg/person, assuming a body weight of 60 kg. And is normally used for food contaminants.

Trophic level. A functional classification of taxa within a community that is based on feeding relationships (e.g., aquatic and terrestrial plants make up the first trophic level, and herbivores make up the second).

Uptake. A process by which materials are transferred into or onto an organism.

Uncertainty. Imperfect knowledge concerning the present or future state of the system under consideration; a component of risk resulting from imperfect knowledge of the degree of hazard or of its spatial and temporal distribution.

Appendices

Appendix 1 Retrospective Risk Assessment: Summary of Likelihood

Summary of Likelihood of Some Identified Agents Causing Decline in Resources

Resource	Likely	Possibly	Unlikely	Unknown
Fisheries	Overfishing	TSS Pesticides DO/BOD/COD Oil & grease Oil spills	Nutrients Coliforms TOC Heavy metals PAH	PCBs, TBT and other organic toxicants Algal blooms
Shellfisheries	Overfishing/ Overcollection DO/BOD/COD	Heavy metals Pesticides TSS Oil & grease Oil spills	Nutrients Coliforms TOC PAH	PCBs, TBT and other organic toxicants Algal blooms
Seaweeds/ algae	Collection TSS	Heavy metals Pesticides Oil & grease Oil spills	Coliforms Nutrients TOC DO/BOD/COD PAH	PCBs, TBT and other organic toxicants Algal blooms
Phytoplankton	TSS	Oil & grease Oil spills	PAH Heavy metals Pesticides Coliforms Nutrients TOC DO/BOD/COD	PCBs, TBT and other organic toxicants

Categories are defined as follows:

Likely (l) – based on knowledge of exposure to the agent and either established effect concentrations (i.e., criteria used in prospective analyses) or other evidence (such as knowledge about intentional harvesting, field observations (e.g. of infestation), the agent is considered to be a likely cause of bay-wide decline in the resource.

Possibly (p) – based on available information about exposure and effect levels, this agent cannot be excluded as a cause of bay-wide decline in the resource.

Unlikely (unl) – based on available information about exposure and effect levels, this agent is unlikely to have caused bay-wide decline in the resource. However, agents in this category may have indirect effects on the resource. For example, nutrients, themselves, would not have a negative effect on benthos (defined here as unlikely), but by enhancing primary productivity (algal blooms), increased nutrients could lead to lowered DO, which is likely to have a negative impact on benthos.

Unknown (unk) – there is not enough information available on exposure and/or effect levels to assess whether agents in this category have led to bay-wide decline in the resource.

These summaries of likelihood were established on the basis of the retrospective analyses (decision tables), on the prospective risk assessments for different agents summarized in the Comparative Risk Assessment section (for water and sediment), on direct field observations (e.g., insect infestation in mangroves) and on information about levels of intentional human activity (e.g., harvesting, clearance). For fisheries, shellfisheries, benthos, seagrass and seaweeds/algae exposure via both water and sediment were assumed. For mangroves exposure was assumed to occur primarily from sediment; for coral reefs and phytoplankton, exposure was assumed to occur primarily from water.

Summary of Likelihood of Some Identified Agents Causing Decline in Habitats

Habitat	Likely	Possibly	Unlikely	Unknown
Mangroves	Clearance Insect infestation (in some areas) Physical disturbance Sedimentation Solid waste	Oil & grease Oil spills Pesticides	Heavy metals Coliforms Algal blooms TOC DO/BOD/COD Nutrients	PCBs and other organic toxicants
Coral Reefs	Sedimentation Collection Physical disturbance (e.g., boat anchorage; inappropriate fishing methods)	Oil & grease Oil spills Nutrients	PAH Pesticides Heavy metals Coliforms TOC DO/BOD/COD	PCBs and other organic toxicants Algal blooms
Seagrass	TSS	Oil & grease Oil spills Heavy metals Pesticides	Coliforms Nutrients TOC DO/BOD/COD PAH	PCBs and other organic toxicants Algal blooms
Soft-Bottoms	Physical Destruction/ Disturbance Fishing activity (i.e., bottom trawling) DO/BOD/COD	TSS Heavy metals Pesticides Oil & grease Oil spills	Nutrients Coliforms TOC PAH	PCBs, TBT and other organic toxicants Algal blooms
Mudflats*		Reclamation** Conversion**		
Sand flats and Beaches*		Reclamation** Conversion** Pollution**		
Rocky Shores*		Reclamation** Conversion** Physical Destruction**		

* later additions; were not part of the original assessment during the workshop

** for lack of sufficient data: inferred as possible factors to cause degradation or loss

Categories defined as follows:

Likely (l) – based on knowledge of exposure to the agent and either established effect concentrations (i.e., criteria used in prospective analyses) or other evidence (such as knowledge about intentional harvesting, field observations (e.g. of infestation), the agent is considered to be a likely cause of bay-wide decline in the resource.

Possibly (p) – based on available information about exposure and effect levels, this agent cannot be excluded as a cause of bay-wide decline in the resource.

Unlikely (unl) – based on available information about exposure and effect levels, this agent is unlikely to have caused bay-wide decline in the resource. However, agents in this category may have indirect effects on the resource. For example, nutrients, themselves, would not have a negative effect on benthos (defined here as unlikely), but by enhancing primary productivity (algal blooms), increased nutrients could lead to lowered DO, which is likely to have a negative impact on benthos.

Unknown (unk) – there is not enough information available on exposure and/or effect levels to assess whether agents in this category have led to bay-wide decline in the resource.

These summaries of likelihood were established on the basis of the retrospective analyses (decision tables), on the prospective risk assessments for different agents summarized in the Comparative Risk Assessment section (for water and sediment), on direct field observations (e.g., insect infestation in mangroves) and on information about levels of intentional human activity (e.g., harvesting, clearance). For fisheries, shellfisheries, benthos, seagrass and seaweeds/algae exposure via both water and sediment were assumed. For mangroves exposure was assumed to occur primarily from sediment; for coral reefs and phytoplankton, exposure was assumed to occur primarily from water.

Appendix 2. Sources of Data

Sources of Data for the Initial Risk Assessment of Manila Bay

Retrospective Risk Assessment

Resource/ Habitat	References
Fisheries	BFAR, 1995
	Tambuyog Development Center, 1990
	FSP-DA, 1992
	UNEP/EMB-DENR, 1991
Shellfisheries	UNEP/EMB-DENR, 1991
	Tambuyog Development Center, 1990
	Blanco, G. J., 1958
Seaweeds	BFAR, 1995
Phytoplankton	BFAR, 1995
Mangroves	BFAR, 1995
	DENR-RIII, 1999
	DENR-NCR, 1999
Corals	BFAR, 1995
	UNEP/EMB-DENR, 1991
Soft-Bottoms	PRRP, 1999
	BFAR, 1995
	UNEP/EMB-DENR, 1991
Seagrass, Mudflats, Sandflats, Beaches and Rocky Shores	BFAR, 1995

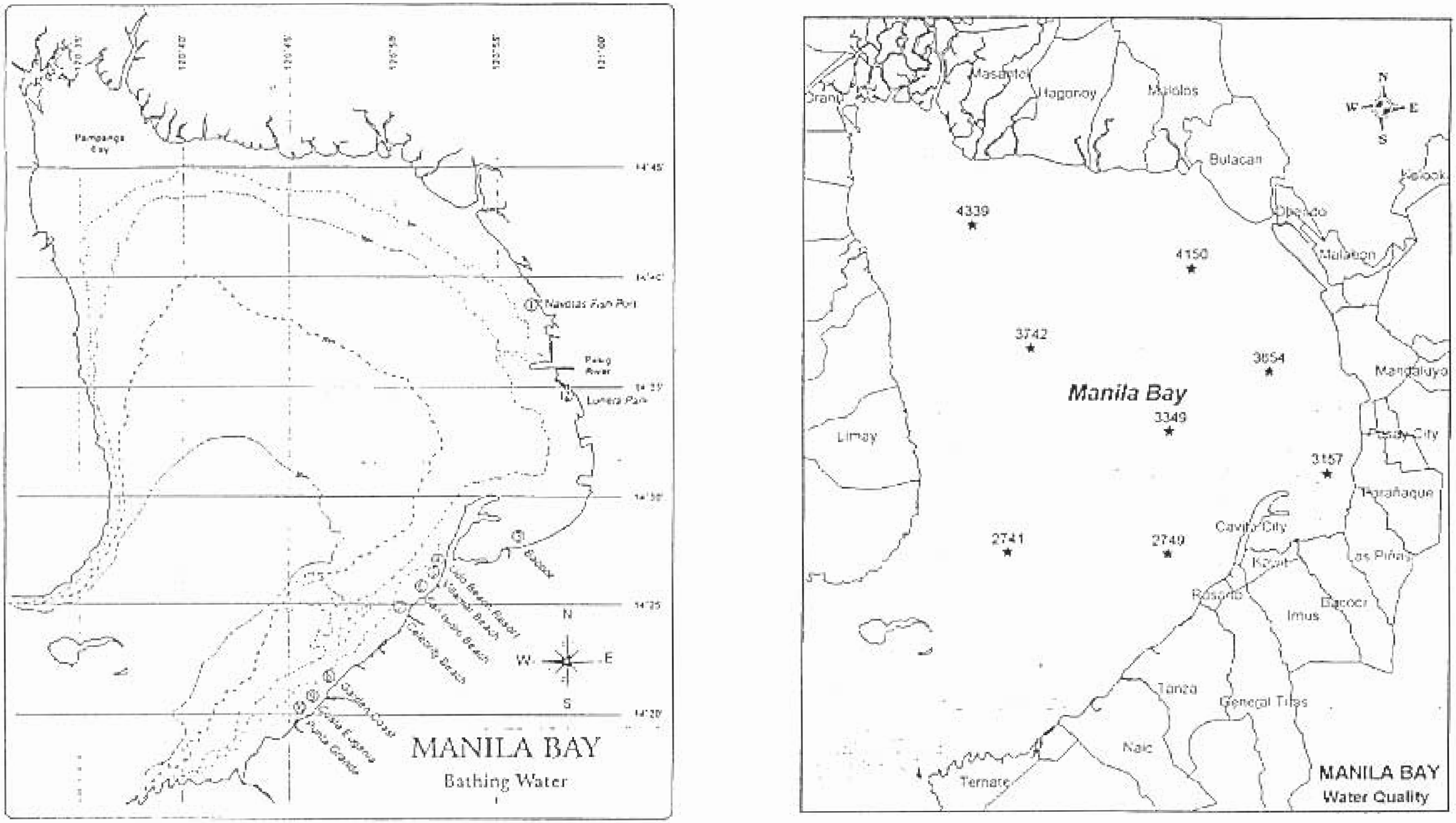
Parameters	Description of Data	Location	References
Nutrients	Raw data: 1996-1998, monthly, 8 stations, 3 depths (SMB)	Entire bay	PRRP, 1999
DO	Raw data: 1996-1998, monthly, 8 stations, 3 depths (SMB)	Entire bay	PRRP, 1999
TSS	Raw data: 1996-1998, monthly, 8 stations, 3 depths (SMB)	Entire bay	PRRP, 1999
Coliforms			
Water column	Raw data: 1996-1998, monthly, 10 bathing stations	Eastern and southern sections	PRRP, 1999 (Main Text)
Tissue	Raw data: 1996-1998, monthly, 10 stations	Bulacan, Parañaque, Bacoor, Kawit and Naic, Cavite	PRRP, 1999 (Annexes)
Heavy metals			
Water column	Raw data: 3 stations, 1 m and 3 m	Meycauayan, Bacoor and Pampanga	EMB-DENR, 1991
	Raw data: Sept-Oct92 (surface), Feb-Mar93 (bottom), 10 stations	River mouths around the bay	BFAR, 1995
Sediment	Raw data: 1996-98, 6 outings, 10-18 stations	Entire bay	PRRP, 1999
	Raw data: 1983-86, 3 stations, surface; depth profiles (0-200 cm)	Meycauayan, Bacoor and Pampanga (nearshore)	EMB-DENR, 1991
	Surface: 10 stations	Bulacan River mouth and Pasig River mouth to ~15 km off-shore	Prudente et al., 1994
	Depth profiles: 5 stations	Bulacan River mouth to ~15 km off-shore	Prudente et al., 1994

Parameters	Description of Data	Location	References
Heavy metals			
Sediments	Ranges: 1994-1996, 9 stations	South and North of bay	Narcise and Jacinto, 1997
Tissue (Fish)	Raw data: 1983-1984, 5 stations	Tanza (Cavite), Manila, Malabon/Navotas, Pampanga River mouth, Limay (Bataan)	EMB-DENR, 1991
Fish and shellfish	Raw data: 1994 and 1996, 16 fish species	Purchased from ports of Coastal Road, Parañaque (April 1994) and Naic, Cavite (March 1996)	Prudente et al., 1997
	Averages (shellfish): May and August 1993, 3 stations	Parañaque, Pampanga, Bataan	BFAR, 1995
	Raw data: Sept and Mar1996; 5 stations	Bulacan, Parañaque, Bacoor, Kawit and Naic, Cavite	PRRP, 1999
Pesticides			
Sediments 16 pesticides	Raw data: Sept and Mar 1996; 10 stations	Entire bay	PRRP, 1999
Tissue (Shellfish) 16 pesticides	Raw data: Sept and Mar1996; 5 stations	Bulacan, Parañaque, Bacoor, Kawit and Naic, Cavite	PRRP, 1999
(Fish) 3 pesticides	Cited values	No stations specified	Tuazon & Ancheta, 1992
PAHs Sediment	Raw data: 1995-1996; 19 stations (W), 16 stations (E)	Western and Eastern side of bay	Santiago, 1997
	Raw data: Sept and Mar 1996; 10 stations	Entire bay	PRRP, 1999
Oil and grease	1985	Bacoor (Cavite), Pasig (Manila), Navotas (Metro Manila), Meycauayan and Pamarawan (Bulacan)	Cited in BFAR, 1995
	1992-1993	Around the bay	BFAR, 1995

Parameters	Description of Data	Location	References
Oil spills	1990-95, 1999: Source, date, area, type and quantity of oil	Bataan and Manila	1990-95: PCG as cited in EMB-DENR, 1996 1999: PCG (pers.comm.)

Appendix 3. Sampling Stations

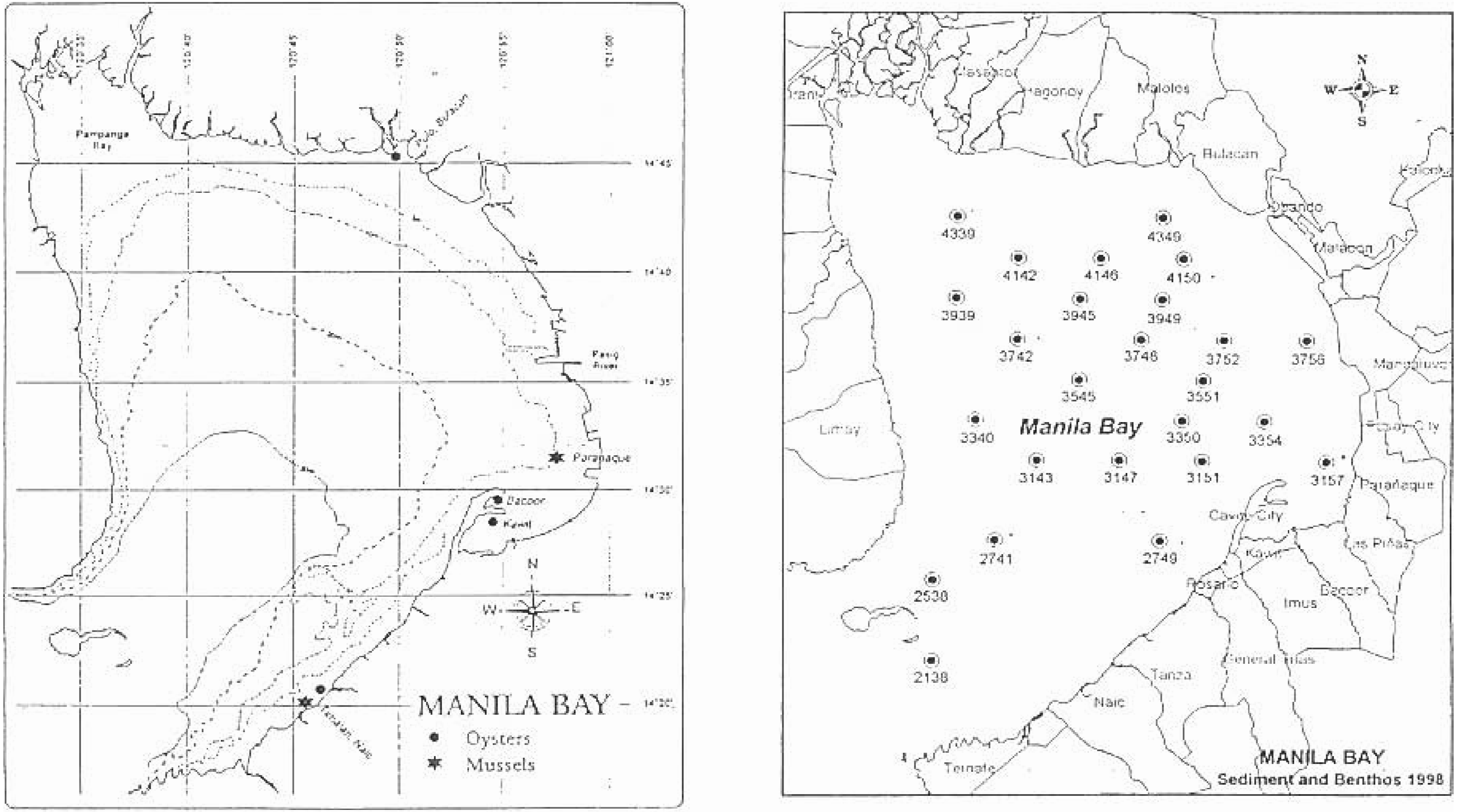
Maps of Manila Bay Showing the Sampling Stations Used by the Pasig River Rehabilitation Program (PRRP, 1999)



(a)

(b)

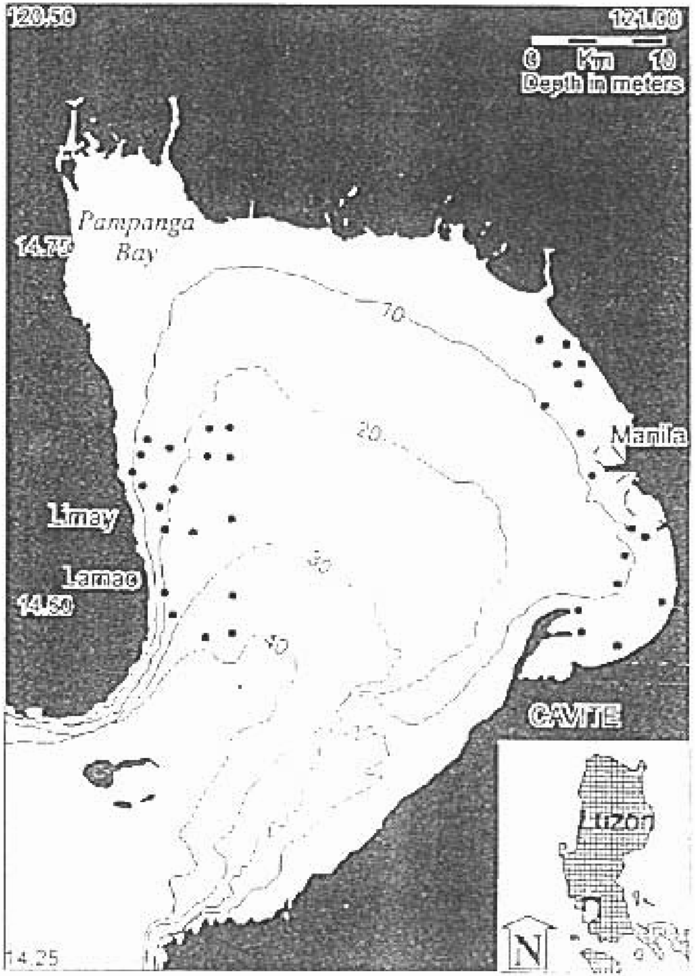
Maps of Manila Bay Showing the Sampling Stations Used by the Pasig River Rehabilitation Program (PRRP, 1999)



(c)

(d)

Map of Manila Bay Showing the Sampling Stations Used by Santiago (1997) for Determination of PAHs in Sediments



(c)

Appendix 4. Criteria/Standards

Water Quality Criteria

Physico-chemical parameters	U.S. EPA Quality Criteria for water for regulatory purposes		Water Quality Criteria for coastal and marine waters in the Philippines (DAO 34) (Classes SA, SB, SC, SD)	ASEAN ~~(Proposed~~ Marine water quality criteria)	Chinese Standards for different classifications (Classes I, II, III, IV)
	Marine acute criteria	Marine chronic criteria			
DO (mg/l)			5,5,5,2	4	6,5,4,3
COD (mg/l)					2,3,4,5
BOD5 (mg/l)			3,5,7,?		1,2,3,4
Nitrate (mg/l)				0.06[1]	
Nitrite (mg/l)				0.055[1]	
Phosphate (mg/l)				0.015-0.045 (coastal - estuaries)	
TSS (mg/l)				50 (Malaysia)	
Cyanide (ug/l)	1	1	50,50,50,?	7	5,5,100,200
Ammonia (ug/l)				70 (unionized)	

notes.

1 single value should be derived for NO3 + NO2 conc [illegible] mean [illegible] maximum

ASEAN

Temp - increase not more than 2°C above the max [illegible] temperature

Water Quality Criteria

for aquatic life protection

Heavy Metals (ug/l)	U.S. EPA Quality Criteria for water for regulatory purposes		Water Quality Criteria for coastal and marine waters in the Philippines (DAO 34) (Classes SA, SB, SC, SD)	ASEAN (~~Proposed~~ Marine water quality criteria)	Chinese Standards for different classifications (Classes I, II, III, IV)
	Marine acute criteria	Marine chronic criteria			
Cadmium	43	9.3	10,10,10,?	10	1,5,10,10
Copper	2.9	2.9	?,20,50,?	2.9 [1]	5,10,50,50
Lead	140	5.6	50,50,50,?	8.5	1,5,10,50
Mercury	2.1	0.025	2,2,2,?	0.16	0.05,0.2,0.2,0.5
Nickel	75	8.3			5,10,20,50
Chromium	1,100	50	50,100,100,? (VI)	48 (VI) [2]	50,100,200,500
Silver	2.3	/			
Zinc	95	55		50	20,50,100,500
Arsenic	69 (Tri)	36 (Tri)	50,50,50,?	120	20,30,50,50
Selenium	410	54			10,20,20,50

[1] Adopted value, for Cu is 8 ug/l – since proposed value 2.9 ug/l is too stringent, the meeting agreed to use round-up value of 7.7 ug/l, the product of the derived LOEC from a chronic 77 ug/l for reproduction for Mysidopsis bahia and a safety factor of 0.1.

[2] Adopted value for Cr(VI) is 50 ug/l – criteria value proposed by CPMS-II is 48 ug/l. The meeting recommended to adopt 50 ug/l, following the existing standards of member countries

Water Quality Criteria

Trace Organics (ug/l)	U.S. EPA Quality Criteria for water for regulatory purposes		Water Quality Criteria for coastal and marine waters in the Philippines (DAO 34) (Classes SA, SB, SC, SD)	ASEAN (Proposed Marine water quality criteria)	Chinese Standards for different classifications (Classes I, II, III, IV)
	Marine acute criteria	Marine chronic criteria			
Chlordane	0.09	0.004	3,?,?,?		
DDT	0.13	0.001	50,?,?,?		0.05,0.1,0.1,0.1
Malathion	/	0.1			0.5,1,1,1
Endosulfan	0.034	0.0067			
Pentachlorophenol	13	7.9			
Heptachlor	0.053	0.0035	/		
Endrin	0.037	0.0023	/		
Aldrin	1.3	/	1,?,?,?		
Dieldrin	0.71	0.0019	1,?,?,?		
Lindane			4,?,?,?		
Toxaphane			5,?,?,?		
Methoxychlor	/	0.03	100,?,?,?		
Benzene	5,100	700			
Phenol				120	
PCBs	10	0.03	1,?,?,?		
PAHs	300	/			
Benzo[a]pyrene					2.5,2.5,2.5,2.5
HCHs					1,2,3.5

Water Quality Criteria

	U.S. EPA Quality Criteria for water for regulatory purposes		Water Quality Criteria for coastal and marine waters in the Philippines (DAO 34) (Classes SA, SB, SC, SD)	ASEAN (Proposed Marine water quality criteria)	Chinese Standards for different classifications (Classes I, II, III, IV)
	Marine acute criteria	Marine chronic criteria			
Organometallics					
TBT (ug/l)				0.01	
Oil & grease (mg/l)	0.09	0.004	1,2,3,5 (Petroleum ether extract)	0.14[1] (Water soluble fraction)	0.05,0.05,0.3,0.5

[1] [illegible] proposed in the future

for human health / welfare :

[illegible] criteria values note

(1) [illegible] / total coastal water for [illegible]

35 [illegible] / total

Sediment Quality Criteria

Heavy Metals	HK-ISQVs (mg/kg)		CANADA (mg/kg)		NOAA (mg/kg)		NETHERLANDS (mg/kg)	
	Contamination Classification		Threshold/probable Effects Level		Effects Range		Provisional Test/warning Value	
	Lower limit	x	Threshold	Probable	Low	Median	Test	Warning
Cadmium	1.5	9.6	[0.68]	4.21	1.2	9.6	7.5	30
Copper	65	270	[18.7]	108	34	270	90	400
Lead	75	218	30.2	112	46.7	218	530	1000
Mercury	0.28	1	0.13	0.7	0.15	0.71	1.6	15
Nickel	40	N/A	[15.9]	42.8	20.9	51.6	45	200
Chromium	80	370	52.3	160	81	370	480	1000
Silver	1	3.7	[0.73]	[1.77]	1	3.7	/	/
Zinc	200	410	124	271	150	410	1000	2500
Arsenic	8.2	70	7.24	[41.6]	8.2	70	85	150

Sediment Quality Criteria

μg/kg — v

Organics	HK-ISQVs (mg/kg)		CANADA (mg/kg)		NOAA (mg/kg)		NETHERLANDS (mg/kg)	
	Contamination Classification		Threshold/probable Effects Level		Effects Range		Provisional Test/warning Value	
	Lower limit	Upper limit	Threshold	Probable	Low	Median	Test	Warning
Acenaphthene	16	500	[6.71]	[88.9]	16	500	/	/
Acenaphthylene	44	640	[5.87]	[245]	44	1100	/	300
Anthracene	85.3	1100	[46.9]	[128]	85.3	640	80	/
Fluorene	19	540	21.2	[144]	[19]	540	/	/
Naphthalene	160	2100	34.6	[391]	160	2100	/	/
Phenanthrene	240	1500	86.7	544	240	1500	[80]	[300]
Low mol. wt. PAHs	552	3160	/	/	552	3160	/	/
Benzo[a]anthracene	261	1600	[74.8]	693	261	1600	80	[300]
Benzo[a]pyrene	430	1600	88.8	763	430	1600	80	[300]
Chrysene	384	2800	108	846	384	2800	[80]	[300]
Dibenzo[a,h]anthracene	63.4	260	[6.22]	[135]	63.4	260	80	300
Fluoranthene	600	5100	[113]	1494	600	5100	200	[700]
Pyrene	665	2600	153	1398	665	2600	[80]	[300]
High mol. wt. PAHs	1700	9600	/	/	1700	9600	/	/
Total PAHs	4022	44792	/	/	4022	44792	[460]	[1700]
Total PCBs	22.7	ns	21.5	189	22.7	180	[20]	[40]

Sediment Quality Criteria

[illegible]

Organics (cont.)	HK-ISQVs (mg/kg)		CANADA (mg/kg)		NOAA (mg/kg)		NETHERLANDS (mg/kg)	
	Contamination Classification		Threshold/probable Effects Level		Effects Range		Provisional Test/warning Value	
	Lower limit	Upper limit	Threshold	Probable	Low	Median	Test	Warning
p,p'-DDE (4,4'-DDE)	2.2	ns	[2.07]	374	2.2	[27]	/	/
Total DDT	1.58	ns	3.89	51.7	[1.58]	[46.1]	2	50
Bis(2-ethylhexyl)phthalate			182	2647				
Chlordane			2.26	4.79				
Lindane			[0.32]	0.99				
Organometallics								
TBT in interstitial water (~~μ~~g /l)	0.15	ns						

μg

(HK ISQV)

Human Health Guidelines

Heavy metals	μg TDI in mg/person/day (mostly from FDA, USA)	Level of Concern mg/g in seafood (low consumption group)	Level of Concern mg/g in seafood (high consumption group)
Arsenic	130	2.95	1.12
Cadmium	55	1.25	0.47
Chromium	200	4.55	1.72
Copper	400 (1-10yr)	9.09	3.45
	2000 (adults)	45.45	17.24
Iron	8000 (1-10 yr)	181.82	68.97
	14000 (adults)	318.18	120.69
Mercury	16	0.36	0.14
Manganese	1000 (1-10 yr)	22.73	8.62
	2500 (adults)	56.82	21.55
Nickel	1200	27.27	10.34
Lead	6 (0-6 yr)	0.14	0.05
	15 (7-adults)	0.34	0.13
	25 (pregnant women)	0.57	0.22
	75 (adults)	1.7	0.65
Zinc	5000 (1-10 yr)	113.64	43.1
	15,000 (adults)	340.91	129.31

Human Health Guidelines

	TDI in mg/person/day	Level of Concern in mg/g in fish	Human health Quality Criteria from Malaysia (ng/l)	Malaysian Aquatic Life Standard (ng/l)	Danish Standard (ng/l)
Pesticides					
Chlordane					
DDT/DDE	80	5	100	4	2
Endosulfan	4.8	0.3	10000	10	1
Heptachlor	4.8		50	60	4
Endrin	4.8	0.3	60		
Aldrin	4.8		20		
Dieldrin	4.8		20	8	10
Lindane	1.6-8	0.1-0.5	2000		
Persistent trace organics					
Total PCBs	14*				

* Lee et al. (1992) Lebebsmittelchemie 46: 90-93.

Organometallics	TDI in mg/person/day	Level of Concern in mg/g in mussels	Environmental Quality Standard in water in the UK (ng/l)
TBT		1	2
Butyltin	15** (based on an average adult weight of 60 kg)		

** Kannan et al. (1995) Environmental Pollution 90:279-290.

PSP toxins	WHO guideline in MU/kg	FDA guideline in ug/100g shellfish tissue
PSP	4000	80