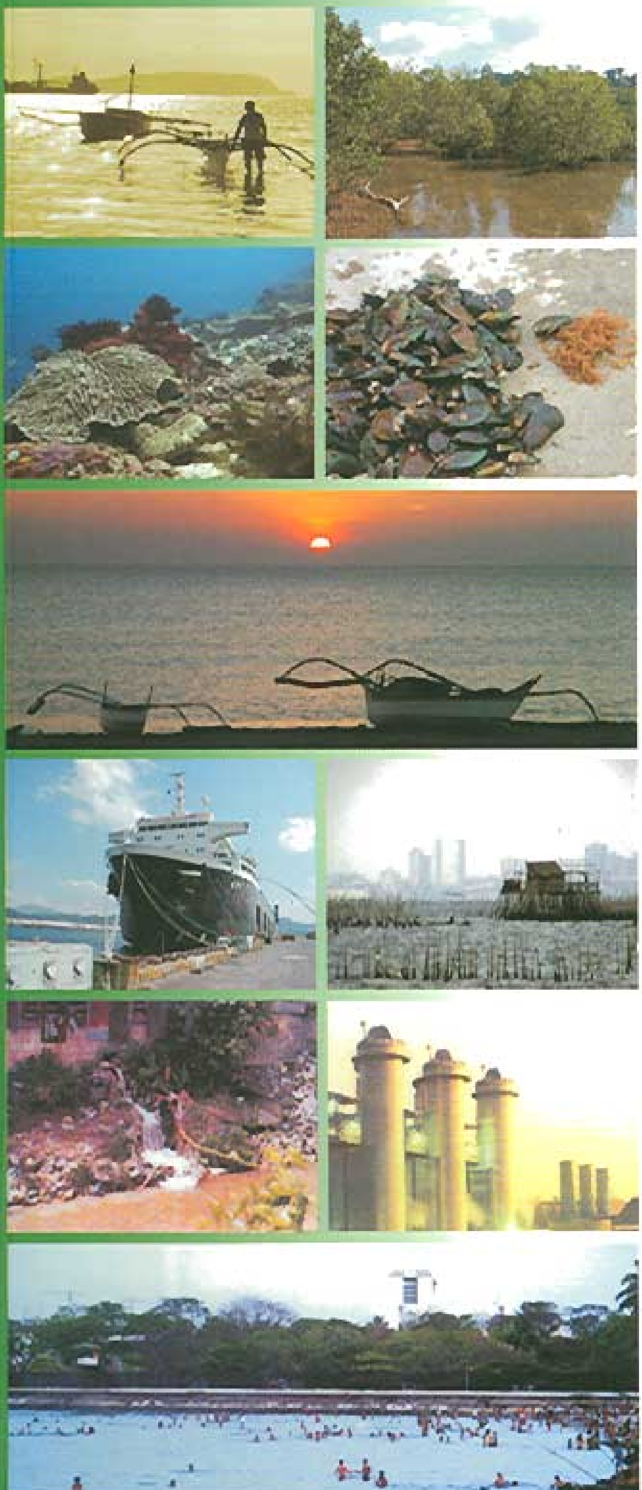
Partnerships in Environmental Management for the Seas of East Asia

Department of Environment and Natural Resources



# Manila Bay

## Refined Risk Assessment

GEF/UNDP/IMO Regional Programme on Partnerships in Environmental Management for the Seas of East Asia

# Manila Bay: Refined Risk Assessment

GEF/UNDP/IMO Regional Programme on Partnerships
in Environmental Management for the Seas of East Asia

**MANILA BAY: REFINED RISK ASSESSMENT**

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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 twelve participating countries are: Brunei Darussalam, Cambodia, Democratic People's Republic of Korea, Indonesia, Japan, 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 |
| CCME | - | Canadian Council of Ministers for the Environment |
| 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 |
| ERA | - | Environmental Risk Assessment |
| FSP-REA | - | Fisheries Sector Program – Resource and Ecological Assessment |
| Geomean | - | geometric mean |
| HAB | - | Harmful Algal Bloom |
| IRA | - | initial risk assessment |
| HK 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 |
| MBEMP | - | Manila Bay Environmental Management Project |
| 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 |
| NCR | | National Capital Region |
| $NH_3$ | - | ammonia |
| $NO_3$ | - | nitrate |
| NOEL | - | no observable effects level |
| 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 |
| POPs | - | persistent organic pesticides |
| PRRP | - | Pasig River Rehabilitation Project |
| PSP | - | paralytic shellfish poisoning |
| QA/QC | - | quality assurance/quality control |
| RDA | - | recommended daily allowance |
| 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) |
| RRA | - | refined risk assessment |
| SEMP | - | strategic environmental management plan |
| TAH | - | total aromatic hydrocarbons |
| TBT | - | tributyltin |
| TDI | - | tolerable daily intake |
| TOC | - | total organic carbon |
| TPAH | - | total polycyclic aromatic hydrocarbons |
| TSH | - | total saturated hydrocarbons |
| TSS | - | total suspended solids |
| TWG | | Technical Working Group |
| USFDA | - | United States Food and Drug Administration |
| USEPA | - | United States Environment Protection Agency |

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**RESOURCES**

1. Dr. Vicente Tuddao, Jr., Department of Environment and Natural Resources (DENR)-Region III (Team Leader)
2. Prof. Nygiel Armada, University of the Philippines (UP)-Visayas, CFOS
3. Dr. Fernando Siringan, UP-National Institute of Geological Sciences (NIGS)
4. Dr. Edgardo Vendiola, Department of Environment and Natural Resources (DENR)-Region IV
5. Ms. Sandra Vic R. Arcamo, Bureau of Fisheries and Aquatic Resources (BFAR)
6. Dr. Rudolf Hermes, Philippine Council for Aquatic and Marine Research Development
7. Mr. William Azucena, BIGKIS, Bataan Project Management Office
8. Mr. Jaime P. Mallare, DENR
9. Engr. Marte P. Ballesteros, Manila Bay Environmental Management Project (MBEMP), DENR

**CONTAMINANTS**

1. Ms. Ella Deocadiz, DENR-Environmental Management Bureau (EMB) (Team Leader)
2. Ms. Imelda Velasquez, UP-Marine Science Institute (MSI)
3. Mr. Arnold Villados, DENR-NCR
4. Lt. Allen Toribio, Philippine Coast Guard
5. Ms. Bernadette Magsumbol, Pasig River Rehabilitation Commission
6. Dr. Reynaldo Palis, Jr., Bureau of Soil and Water Management, DA

7. Dr. Romeo Quijano, UP-Dept. of Pharmacology, College of Medicine
8. Mr. Reynaldo P. Alcances, DENR-EMB
9. Dr. Joselito Duyanen, UP-NIGS
10. Mr. Robert L. Co, DENR-EMB

**HUMAN HEALTH**

1. Engr. Gerardo Mogol, Department of Health (Team Leader)
2. Engr. Victorio Molina, UP-College of Public Health
3. RTD Neria Andin, DENR-NCR
4. Ms. Nilda S. Baling, DENR
5. Ms. Vilma Cabading, DENR-EMB
6. Mr. Allan L. Leuterio, DENR-EMB
7. Dr. Godofreda V. Dalmacion, UP-Dept. of Pharmacology, College of Medicine
8. Dr. Mario S. Baguilod, Department of Health

**HARMFUL ALGAL BLOOM**

1. Dr. Rhodora Azanza, UP-MSI (Team Leader)
2. Ms. Fe Farida A. Bajarias, BFAR
3. Ms. Elvira Z. Sombrito, Philippine Nuclear Research Institute, DOST
4. Ms. Leza Acorda, DENR-EMB

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The Manila Bay: Refined Risk Assessment project was managed by Mr. S. Adrian Ross, Senior Programme Officer, PEMSEA RPO.

# Definition of Terms

*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).

*Algicides.* Are compounds used in ponds commonly copper sulfate ($CuSO_4 \cdot 5H_2O$), simazine (2-chloro-4, 6-bis (ethylamino) S- triazine, and Solvicin 135 (potassium ricinoleate. They inhibit both respiration and photosynthesis in algae.

*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.

*Bacteria enzymes/amendments.* Bacteria capable of fixing nitrogen and mineralizing phosphorus are recently used on aquaculture ponds because they are claimed to increase nutrient concentration.

*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.

*Fertilizers.* Chemical or organic compounds which are applied to fish ponds to increase inorganic nutrient concentrations and favor greater phytoplankton growth.

*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.

*Herbicides*. used on agricultural crops can contaminate ponds. Even though these materials may not be appreciably toxic to aquatic animals. They may harm phytoplankton. Propanil [N-(3-4-dichlorophenyl) propanamide] which is sprayed on rice fields for weed control, reduces oxygen production by phytoplankton communities.

*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.

*Oxidants.* Especially potassium permanganate tend to oxidize organic and inorganic substances and kill bacteria, thereby reducing the rate oxygen consumption by chemical and biological process.

*Pesticides*. Are number of chemicals which are used on agricultural crops. Acute toxicity values for many commonly used insecticides range from 5 to 100 ug/liter, and much lower concentrations may be toxic upon longer expose.

*Piscicides*. Complex organic compounds used as fish toxicant. Rotenone, is commonly used which occurs along with related compounds in the roots of *Derris elliptica*, *Conchocarpus spp.* and few other leguminous plants. It interferes with respiration and is extremely toxic to fish at low concentration.

*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,

$$B = \frac{\left(\overline{Cw/a}\right) * A}{X1}$$

where $\left(\overline{Cw/a}\right)$ 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).

*Therapeutants.* Chemical compounds such as potassium permanganate which are used to treat fish diseases and are highly phytotoxic.

*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 by 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. The TDI is the amount that may be consumed every day over a lifetime without causing harm, based on currently available literature.

*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.

# Executive Summary

## Objectives

This report presents the findings and outcome of the refined risk assessment of Manila Bay which was undertaken by an inter-agency, multi-disciplinary Technical Working Group (TWG) created by PEMSEA/DENR-MBEMP. The report was based to a large extent on the document, "Manila Bay Initial Risk Assessment" which was published by PEMSEA/DENR in April 2001. The objectives of the refined risk assessment were:

- Review the initial risk assessment of Manila Bay in order to determine if there are other new or additional data which could be included and to examine the effect of such new or additional data on the conclusions and recommendations made during the initial risk assessment;
- Identify sources of and activities that contribute to pollution in the bay;
- Evaluate the impacts of pollutants in Manila Bay on human and ecological targets and identify those pollutants that should be given priority in risk management or remediation programs;
- Recommend measures to reduce or eliminate identified risks of significance to the bay;
- Identify data gaps in the refined risk assessment of Manila Bay that need to be addressed and uncertainties that need to be verified through monitoring and research/ studies that generate primary data; and
- Strengthen local capability of and collaboration among agencies and institutions that can play significant roles in the long-term management of Manila Bay

## Risk Assessment

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, however, 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 by stopping the activity that produces it. Another approach is to prevent the contaminant level from exceeding an allowable (threshold) level which, based on scientific evidence, presents acceptable risk. Elimination of contamination to zero concentration may require large investments, and discontinuing economic activities to prevent the release of these contaminants 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 do 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, intentional 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.

Risk assessment is one of the six component activities of the Manila Bay Environmental Management Project (MBEMP). 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). ERA can be carried out, independently or concurrently, in two directions. Retrospective risk assessment attempts to answer the question: "what evidence is there for harm being done to targets in the bay?" Prospective risk assessment, on the other hand, tries to answer the question: "what problems might occur as a consequence of conditions known to exist, or possibly exist in the future?" Depending on details, these could be conducted in a variety of simple or more sophisticated ways.

PEMSEA has adopted both the retrospective and prospective approaches to risk assessment. In addition to generating specific results, each approach serves to strengthen the results of the other. The ERA process starts simply through an initial risk assessment (IRA) and progresses to a more refined risk assessment (RRA) if the results warrant and available data allow more in-depth analysis.

The retrospective and prospective risk assessments are preceded by a problem formulation stage, where the agents, appropriate targets, assessment endpoints, and corresponding measurement endpoints are defined. 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 considerable time to measure. So other features related to the assessment endpoints, 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).

For the retrospective risk assessment, changes or evidence of decline/deterioration in the resources and habitats of the bay as well as changes in the physical features of the bay were evaluated based on available measurement endpoints. Ascribing a causal agent for the decline, retrospectively, is difficult and is usually based upon weight of evidence. The likelihood that the suspected or possible agents may have actually caused these changes were determined using a pre-established set of questions tabulated into so-called decision tables. The questions/criteria in the decision tables increase confidence in judgments about a causal agent, and are needed (but not necessarily sufficient) conditions to establish the causal agent. Related information that can support the identified relationships between the decline in targets and suspected agents are useful in strengthening the assessment.

For the prospective risk assessment, PEMSEA adopted the risk quotient (RQ) approach, which 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.

For the assessment of ecological risks, the RQ approach was carried out using standards and criteria values from the literature as thresholds, referred to as Predicted No-Effects Concentration (PNEC), to estimate the risk to the entire ecosystem. The RQ is simply the ratio of the measured environmental concentration (MEC) from available data to the PNEC.

For human health, the fairly simple and straightforward RQ approach was also adopted, although preliminary exposure assessment for certain heavy metals to calculate actual doses obtained was performed in the RRA and presented as additional information. The RQ for human health risk assessment is the ratio of the Measured Environmental Level (MEL), which is equivalent to the measured concentrations of the agent in seafood (tissues of fish or shellfish), to the Level of Concern (LOC). LOCs, in turn, are obtained by dividing the Tolerable Daily Intakes (TDIs) by the average consumption rates. The TDI is a regulatory value equivalent to the acceptable daily intake established by relevant regulatory bodies and agencies (just like the PNEC), e.g. United States Food and Drug Administration (USFDA), World Health Organization, and the European Commission Scientific Committee on Food. The TDI is the amount that may be consumed every day over a lifetime without causing harm, based on currently available literature. It is expressed in mg/person, assuming a body weight of 60 kg. and is normally used for food contaminants.

For both ecological and human health risk assessment, when an RQ is less than one, it is presumed that the likelihood of adverse effects is low. When an RQ is greater than one, there is a likelihood of adverse effects the magnitude of which increases with increase in RQ.

RQs in this paper are expressed as $RQ_{Geomean}$ or $RQ_{Max}$. The $RQ_{Geomean}$ was obtained by calculating the geometric mean of MECs from a set of data and dividing it by the PNEC. The geometric mean MEC was preferred to the arithmetic mean MEC since data of this kind often follow a log normal distribution, and in such cases the geometric mean will provide a less biased measure of the average than will the arithmetic mean. The $RQ_{Max}$ gives an estimate of the worst or highest RQ based on a set of available data, by selecting the highest observed MEC and dividing it by the PNEC. The variability between the $RQ_{Geomean}$ to the $RQ_{Max}$ provides an initial measure of uncertainty. A more quantitative measure of uncertainty was 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.

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 and TDIs. Although there may be uncertainties associated with the MECs and PNECs/TDIs 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.

The IRA of Manila Bay was conducted as a preliminary step to the RRA. It provided a glimpse of environmental conditions in the bay using available secondary data. It served 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 identified contaminants that present acceptable risks and hence, may not need further assessment, and highlighted contaminants that present risks to the environment and/or to human health. It also identified resources and habitats that are at risk and recognized significant causes of risks. The results of the IRA were used to formulate an action plan for a more comprehensive risk assessment (refined risk assessment) that is focused on the identified priority areas of concern. Evaluating the results of the IRA also facilitated improvement and refinement of the methods used.

The IRA drew attention to the importance of collaboration among different government agencies, universities and scientific and technical research institutions considering the different 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. This became the basis for the creation of a multi-disciplinary, inter-agency TWG commissioned to undertake the refined risk assessment. Sharing of information and access to existing data in the RRA was facilitated through the TWG.

In the RRA, the data used in the IRA were verified and updated. The quality of data which became the basis for the prospective risk assessment, was assessed through a scoring system to reduce uncertainties. The scoring system was based on the documentation of procedures and adoption of quality assurance/quality control (QA/QC) procedures in sampling and laboratory analysis and was the same as that adopted by the ASEAN-Canada Cooperative Programme on Marine Science (CPMS) II - Environmental Criteria Component. To the extent possible, the recommendations in the IRA on additional data needed to expand the risk assessment process were followed. This included an analysis of shoreline changes and its effects on resources and habitats as part of retrospective risk assessment. Available data on pesticides, although limited, were added to estimate the risks due to pesticides from agricultural activities and pesticide manufacturing. Data on oil and grease from 1975 to 2001 were analyzed as recommended in the IRA to determine the relative importance of land-based to sea-based sources. New data on several heavy metals in the water column were considered in assessing the risks due to heavy metals.

In prioritizing risk management actions for human health issues, the agents were ranked according to the calculated RQ. However, it must be recognized that the RQ may not take into account cumulative effects and synergistic effects of several agents that co-exist within the bay. Further, in ranking agents based on RQ, it was assumed that the tolerable daily intake that was used in calculating the RQ was arrived at taking into consideration relative toxicity, persistence and bioaccumulation potential, although this may not necessarily be the case. Finally, a major uncertainty in assessing human health risks is the absence of local values for TDIs and the fact that age-specific TDIs for some agents, which can account for the relative sensitivity of specific age groups, especially infants and children, as well as pregnant and lactating women, are not available. Thus, preliminary exposure assessment was performed in the RRA to estimate the actual doses received by these critical groups as additional information that can guide risk managers and as initial steps towards in-depth epidemiological studies.

In finalizing the RRA, the TWG took into consideration not only the recommendations in the IRA but also the comments during the peer review of the draft. For instance, changes in bathymetry and oceanographic features and concomitant effects on resources and habitats were added. Soft-bottoms, mudflats, sandflats, beaches, and rocky shores were taken together as one section. Although there are presently no available local data on organotins, which is an anti-fouling agent for ships, its potential impact especially on mollusks, was discussed. Marine debris (solid wastes) were also included in the prospective risk assessment. Correlation or linkages between the results of the retrospective and prospective risk assessments were analyzed.

In the RRA, more precise characterization of contamination with respect to spatial distribution (horizontally and vertically) was accomplished using contour plots (Surfer software) geared at identifying hot spots and determining the relative contribution of various sources of contamination. Seasonal and other temporal variations were also analyzed to the extent possible. A three-dimensional hydrodynamic model of Manila Bay developed by Seaconsult Inc. can be used to predict the levels and distribution of selected contaminants. This model incorporates information on contaminant releases, inputs from tributaries and major point sources, fate of pollutants and the hydrodynamics of the bay. More sophisticated techniques were used to improve uncertainty analyses. Although the RRA was also based mainly on secondary data, primary data were collected to the extent possible for certain parameters for which data are not available.

The results of the risk assessment – what is at risk and how it can be protected against the risk – are essential to ensure sustainability. It gives management decisions a certain degree of confidence and provides 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. Specific recommendations on possible action plans or strategies to manage the risks or to solve, reduce, or remedy the identified priority environmental concerns were made following the completion of the refined risk assessment.

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 into the operational plans for the Manila Bay Coastal Strategy.

## RETROSPECTIVE RISK ASSESSMENT

### Resources, Habitats and Physical Changes

In the RRA, qualitative and quantitative changes in resources, habitats, shorelines and oceanographic features were assessed with reference to earlier observations to determine if these changes are significant, particularly in terms of evidence of decline or changes. Potential agents of these changes were identified. The likelihood that these agents caused the observed changes in resources and habitats were evaluated using a pre-established set of questions, similar to a scoring system (described in Section 3.2.3). The results of the evaluation are summarized in Appendix 1. Changes in shoreline and oceanographic features as a result of human activities and concomitant impact on resources and habitats were also evaluated.

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 (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), the reports prepared by the Department of Environment and Natural Resources (DENR) Region 3 (1999) and the National Capital Region (1999) on the watersheds of Manila Bay within their respective jurisdictions, and the papers published by Armada (2001) and Silvestre *et al*. (1987). More recent data on coral reefs, mangroves, seaweeds and seagrasses were obtained from the 1996 ICLARM Report (Bonga et al., 1996). Data for shoreline and oceanographic changes were obtained mostly from the Manila Bay Environmental Profile, EIS report (PNOC, 1994), and the technical reports of Siringan and Ringor (1997 and 1998). The sources of data are listed in Appendix 2a.

The resources considered include: (1) fisheries; (2) shellfisheries; (3) seaweed; and (4) phytoplankton. For habitats, the following were assessed:(1) mangroves; (2) coral reefs; (3) seagrass beds; and (4) soft-bottoms, mudflats, sandflats and beaches, and rocky shores. Shoreline, oceanographic and bathymetric changes which, in turn, have an effect on coastal habitats and resources, were discussed in a separate section (physical changes).

## RESULTS OF RETROSPECTIVE RISK ASSESSMENT

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.

Manifestations of the decline in quantity of fisheries include: (1) decline in trawl catch per unit effort or CPUE (kg/hr) from 46 to 13.8 during the period 1947-1959 to 14 to 10 for the years 1986-1993; (2) decline in demersal biomass from 4.61 mt/km$^2$ or 8,290 tons in 1947 to about 10 percent, i.e., 0.47 mt/km$^2$ or 840 tons in 1993; (3) exploitation of demersal fisheries far beyond the bay's maximum sustainable yield or MSY; (4) increase in number of fishers per km of coastline by 360 percent, i.e., from 70 in 1987 to 253 in 1993; and (5) increase in number of boats per km coastline by 140 percent, i.e., from 74 in 1980 to 105 in 1993.

Manifestations of the deterioration in quality of fisheries include: (1) change in trawl catch composition from economically valuable to less valuable species; (2) decrease in the relative abundance of finfish and increase in invertebrates of the demersal fisheries; (3) increase in the relative abundance of pelagic species in the demersal trawl catch; (4) disappearance/near-absence of some species (e.g. lizard fish and flat fish); (5) disappearance of larger individuals; and (6) dominance of immature individuals.

For shellfisheries, unstable production of commercially valuable mussels and oysters, disappearance of the windowpane oyster, and contamination of shellfish, particularly with fecal coliforms, are other manifestations of poor management of shellfisheries with consequent deterioration in quality.

For fisheries and shellfisheries, the identified primary agents were overcollection, as a result of growth and recruitment overfishing, 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 in 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 organisms. 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.

Growth overfishing occurs when fish are caught before they have a chance to grow and it is caused by extremely high fishing effort and use of inappropriate mesh size. Recruitment overfishing, on the other hand, occurs when so few adult fish are left in a given exploited stock that the production and natural survival of eggs and larvae is reduced to the extent that recruitment to the fishery is impaired. This is caused by both the reduction of the spawning stock, which may result in the production of a limited number of eggs and larvae, and coastal environmental degradation, which usually affects the quality and size of the nursery areas. All of these have already occurred in Manila Bay.

Socio-economic considerations can also have a bearing on the density of fish resources in Manila Bay. As stressed in the implementing rules and policies for management and conservation of the fisheries and aquatic resources of the Philippines, all users of municipal waters are authorized or permitted to operate within about ten (10.1) to fifteen (15) kilometers from the shoreline. The number of municipal fishermen compared to commercial fishermen is higher such that most fishermen are concentrated in the zone between 4 to 20 km from the shore. Close competition for higher yield in the fishing areas will result in over-fishing and lead to decline in fish resources. Enforcement of laws and regulations is costly. This is the problem encountered for management of commercial and municipal fishing in the Philippines, especially in the case of tuna fishing (Arce, 1988).

Nitrogen loading from aquaculture farms is not only toxic to the fish but also stimulates eutrophication. Nutrient loadings from fish cages enter marine waters in the form of nitrate, ammonia, total organic nitrogen or total nitrogen (Saynor, 1996). The Manila Bay coastal zone has approximately 33,853 ha of fishpond area as of 1995. Problems arise because of the large volumes of water discharged from intensive farms, compounded by the high density of farm units in areas with limited water supply and inadequate flushing. Intensive aquaculture practices pose further damaging effects to the fishery resources through the use of chemical and biological products to solve the self-polluting characteristics of intensive ponds.

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 harmful algal bloom episodes on the demand for shellfish from the bay.

It was estimated that there were around 54,000 ha 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 ha left, which were further reduced to 794 ha based on computations in 1995. The following provinces have had the most significant mangrove forest losses: Pampanga, Bataan and Bulacan, and the town of Navotas in Metro Manila. 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 agents. 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 present status of the coral reef resources of Manila Bay is generally classified as in poor to good condition. The average cover of living corals (both hard and soft) in Manila Bay was estimated to be 40 percent or fair condition. The decline in coral cover was attributed to physical destruction from collection activities, improper fishing practices, as well as smothering of the corals due to increased sedimentation, which in turn, is due to erosion, reclamation, and other land-use conversion activities on land. The levels of certain chemical contaminants in the water column and sediment 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 concentrations, coupled with the elevated levels of nutrients that are required for primary production, suggest that in general, phytoplankton is not at risk in the bay. However, it should be noted that certain species could be harmful or toxic, such as those that lead to paralytic shellfish poisoning in humans or to fish kills. Thus, certain species can be treated as an indicator of ecological problems (as signal of eutrophication and harmful phytoplankton blooms).

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

Mean abundance declined from 706 total/$m^2$ in 1996 to 118 total/$m^2$ in 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 7.9 and 1.0 g ww/$m^2$ in March and November 1998). It was also noted that benthos annelids were mostly polychaetes larvae and that the presence of *Capitellidae* and *Spionidae* (annelids) is an indication of habitats under stress due to high organic pollution and sulfidic conditions (PRRP, 1999). 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.

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

Changes in shoreline position along the bay have an adverse effect in terms of destruction or loss of habitats. Coastal erosion causes severe problems both economically and ecologically. It can result in considerable property damage and may cause disastrous impact on human lives. Land loss may also cause adverse effects on biological productivity due to loss of habitat particularly, seagrass beds and coral reefs.

Shoreline changes are clearly due to human activities that resulted to sediment trading. These are reclamation works along the bay, construction of fishponds or aquaculture along the bay, deforestation, and construction of flood mitigation structures, which likely result to land progradation. Conversely, shoreline changes resulting in land erosion can be attributed primarily to decrease in sediment input from inland due to dams and other river works.

Oceanographic changes, and more specifically, bathymetric changes, can also result to damage of coastal habitats like coral reefs and seagrass beds. Depth changes can significantly distort biological processes of the normal physical environment and of marine flora and fauna (i.e. seaweed and seagrass), which may, in turn, induce changes in species composition and distribution.

For bathymetric changes, the identified likely agents are total suspended solids (TSS) and sediment deposition. Increased TSS induced shallowing while land reclamation, land conversion, construction of fishponds for aquaculture, and lahar flow in the northwestern part of Manila Bay have altogether brought about sediment deposition. Extreme oceanographic forces, like currents and waves, are other possible agents that can cause deepening.

The overall state of the resources and habitats in Manila Bay point to the urgent need for improved management of these resources, long-term planning and zonation that can ensure sustainable development, and stronger implementation of protective regulations and laws that can avert the inevitable consequences of over-exploitation and destruction of these valuable resources and habitats.

## PROSPECTIVE RISK ASSESSMENT

### Contaminants, Ecological Risks and Human Health Concerns

In the prospective risk assessment, potential stressors in Manila Bay were identified and the MECs of these stressors were compared with threshold values or PNECs to obtain RQs. The PNEC represents a value above which an effect is probable and below which an effect is not probable. 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 (PRRP) 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), and the Philippine Environmental Quality Report for 1990-1996 (EMB-DENR), published articles from scientific journals and proceedings, and data provided directly by several TWG members based on their research. A detailed list of the sources of data for each parameter is given in Appendix 2b. The list includes description of the data, sampling stations, and references.

Data quality was assessed based on the documentation of procedures and adoption of QA/QC procedures in sampling and laboratory analysis. The scoring system was based on that adopted by the ASEAN-Canada Cooperative Programme on Marine Science (CPMS) II - Environmental Criteria Component. Data quality score is from one to three, where one denotes data with well documented QA/QC procedures adopted in sample collection and analysis. A score of two denotes data generated where procedures employed are generally satisfactory, i.e., some standard methods have been followed, but one or more pieces of information are missing. A score of three denotes data generated where procedures are poorly documented or where the values are cited without proper documentation or explanation. Except where otherwise indicated, the quality of the data used in the prospective risk assessment to determine ecological effects can be assumed as having a score of one.

The PRRP (1999) study was conducted from 1996-1998. This study covered eight monitoring stations for water column on a monthly basis and thus provided the most extensive spatial study of the water column in Manila Bay to date. Nonetheless, it must be borne in mind that the stations covered may still not necessarily represent the exact conditions in the entire bay. The PRRP sampling stations for water quality, sediment and shellfish tissue are presented in Appendix 3 (a-d).

The selection of PNECs to be adopted presented difficulties particularly in cases where there are no established Philippine values. The choice of PNECs was based on what was available with the assumption that these values are suitable for Manila Bay. Most criteria and standards available have been generated in temperate regions and may not be applicable to a tropical area. The application of the threshold values or PNECs was therefore based on the following scheme: the local criteria values, i.e., Water Quality Criteria for Coastal and Marine Waters in the Philippines, were initially applied. Although this set of criteria was formulated mainly to protect fish production rather than prevent human health effects, it is nonetheless specific to local conditions. In the absence of local criteria values, the ASEAN Marine Water Quality Criteria (ASEAN, 2003) and criteria values from ASEAN countries were then applied. Subsequently, other tropical jurisdictions, e.g., HK ISQV Sediment Quality Criteria, were applied. Finally, the criteria values from other jurisdictions, e.g., United States, were applied. The Philippine criteria for coastal and marine waters were based on background levels and criteria limits of other jurisdictions. The ASEAN marine water quality criteria were based on a comprehensive evaluation of toxicological data for a minimum of six tropical marine species and concentration levels prevailing in tropical environments, following the method of the Canadian Council of Ministers for the Environment (CCME). The United States Environmental Protection Agency (US EPA) criteria are based on marine chronic and acute criteria for regulatory purposes. In cases where the PNECs for a specific agent vary considerably, the range of possible RQs is indicated in the discussion.

For sediment quality, the Hong Kong Interim Sediment Quality Criteria Value (HK ISQV) (EVS Environment Consultants, 1996), were used in the absence of locally derived criteria. The HK ISQV consisted of a lower limit below which the sediment is considered uncontaminated and an upper limit above which the sediment is considered highly contaminated. Contaminant levels in between the two limits indicate moderate contamination. To be conservative, the more stringent lower limit was applied. When the RQ exceeded one, the upper limit was also used to determine if the RQ would still exceed one, which would then indicate that the agent in question requires attention. For comparison, the more conservative shale values which are based on baseline values were also used for heavy metals in sediment. These shale values represent a good approximation for geogenic metal concentrations in sediment in the absence of cores age-dated back to pre-industrial sediment deposition, but not necessarily the values above which there may be unacceptable risks.

The table at the bottom of this page shows the PNECs applied for each parameter considered.

| No. | Parameter | Matrix | PNEC Applied |
|---|---|---|---|
| 01 | Fecal and Total Coliform | Water column (bathing beaches) | Water quality criteria for coastal and marine waters (DAO 34/1990) |
| 02 | Heavy metals | Water column | DAO 34/1990<br>ASEAN marine water quality criteria<br>US EPA marine chronic and acute criteria for regulatory purposes |
| | | Sediment | Shale values<br>Hong Kong interim sediment quality criteria value (HK ISQV)<br>Background value for Cu from a dated sediment core sample from Manila Bay |
| 03 | Pesticides | Water column | US EPA marine chronic and acute criteria for regulatory purposes |
| | | Sediment | HK ISQV |
| 04 | Nutrients | Water column | ASEAN marine water quality criteria |
| 05 | Dissolved oxygen | Water column | DAO 34/1990 |
| 06 | Total suspended solids | Water column | Malaysian water quality criteria |
| 07 | Polyaromatic hydrocarbons | Sediment | HK ISQV |
| 08 | Oil and grease | Water column | DAO 34/1990 |

In general, $RQ_{Geomean}$ and $RQ_{Max}$ were calculated for all contaminants. For contaminants with sufficient data sets, temporal and spatial analysis of RQs were undertaken. Annual and seasonal variations of coliforms, nutrients, DO, and TSS were reflected in both tabular forms and contours, as well as classed post maps using Surfer software. In cases where RQs were generally <1, contour/classed post maps were no longer generated.

In assessing human health risks, the TDI divided by the average consumption rate gave the LOC. As mentioned previously, there are uncertainties associated with the application of the TDI. A major uncertainty in its use is that there are no Philippine values for TDI. The TDIs used were adopted mainly from the United States Food and Drug Administration (US FDA) (http://vm.cfsan.fda.gov, cited in MPP-EAS, 1999b) and were based on a 60-kg man. It is recognized that there are anatomical and metabolic differences between Asians and Caucasians, particularly in terms of body weight. The US FDA TDIs used were mostly for adults although it is generally assumed that infants and children are more sensitive than adults to certain contaminants such as heavy metals.

The rates of seafood consumption are local values obtained mainly from the Food and Nutrition Research Institute of the Department of Science and Technology (FNRI/DOST) based on their nationwide basket survey conducted in 1993. Subject to availability of data, age-specific consumption rates were used in the calculations. The list of criteria is presented in Appendix 4.

Harmful algal blooms, also commonly referred to as red tide, is a problem that has affected Manila Bay in recent years with serious socio-economic impact. It is caused by dinoflagellates, more specifically, *Pyrodinium bahamense* var. *compressum,* and can cause loss of lives due to paralytic shellfish poisoning and significant economic losses. The risks due to harmful algal bloom cannot be expressed in terms of RQs and a different approach was used to assess risks associated with toxicity.

Average and worst-case (maximum) RQs 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 degree of 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. Section 5 shows the results of the comparative risk assessment.

## RESULTS OF PROSPECTIVE RISK ASSESSMENT

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 certain heavy metals (mercury and lead) and pesticides (aldrin and heptachlor) in tissue indicate that these are also priority concerns.

2. In the water column, the $RQ_{Geomean}$ exceeded one for coliforms (total and fecal), phosphate, and heptachlor indicating that these are the contaminants of priority concern. For oil and grease, $RQ_{Geomean}$ exceeded one if only the most recent data (2001) are considered, signalling deteriorating conditions for oil and grease in the water column. High RQs for DO, TSS, and ammonia were also obtained in certain areas. The $RQ_{Geomean}$ and $RQ_{Max}$ for mercury, lead, and copper exceeded one for samples obtained from the mouths of rivers draining into the bay, if the more stringent US EPA criteria, rather than the local DENR DAO 34 criteria are applied as PNEC. For DO, although the $RQ_{Geomean}$ did not exceed one, low DO conditions over short periods may have considerable impact on fauna, particularly benthic animals. The data on pesticides was based on the limited data available and should be verified using other data in the long term.

3. In the sediment, relatively extensive contamination of the bay sediment with mercury and copper was observed where $RQ_{Geomean} > 1$ if the HK ISQV low limit is used as PNEC. If the HK ISQV upper limit is applied for mercury and the background value obtained from a dated sediment core sample from the bay is applied for copper, the areal extent where RQ > 1 is reduced to a few hot spots. The persistence of certain pesticides was noteworthy, considering that these continue to be detected in the sediment which serves as final repository of inputs into the bay, despite their discontinued use or being banned. Total polycyclic aromatic hydrocarbon (TPAH) and an isolated value of dibenzo(a,h)anthracene, a carcinogenic PAH, showed intermediate risk.

In terms of ecological risks, the following should be given priority on the basis of $RQ_{Geomean}$ exceeding one: total and fecal coliform > phosphate > heptachlor in the water column, and mercury and copper in sediment. For the other parameters for which $RQ_{Geomean}$ values are below one, localized risks are indicated when the $RQ_{Max}$ exceed one. $RQ_{Max}$ exceeded one for: heavy metals (mercury, lead and copper) > oil and grease in the water column and cadmium, chromium, lead and zinc and TPAH and dibenzo(a,h)anthracene in sediment.

To prevent adverse health effects, the following should be given priority on the basis of RQ, bioaccumulation potential, and toxicity: fecal coliform in shellfish, lead and mercury in fish and shellfish; and heptachlor and aldrin in fish. In the next order of priority is cadmium, copper and zinc in shellfish and endosulfan sulfate, endosulfan I and endrin in shellfish.

The results of the prospective risk assessment highlight the urgent need for decisive steps to reduce the disturbing levels of fecal coliforms in the bay which have also contaminated shellfish. Among the heavy metals, mercury and lead in fish and shellfish should be monitored, considering their relative toxicity. Efforts at monitoring for pesticides and toxic algae are deemed necessary on the basis of the results of prospective risk assessment. The sources of these contaminants in the water column and sediment, which eventually work their way to fish and shellfish and ultimately to man, should be controlled more effectively.

## SUMMARY OF RECOMMENDATIONS

Recommendations and proposed action plans based on the results of the retrospective and prospective risk assessments are presented and discussed in Section 8. These recommendations, in brief, are listed as follows:

**On Resources**

1. Improve and strengthen fisheries and shellfisheries management in the Bay.

2. Include in the overall Operational Plan of the Manila Bay Coastal Strategy (OPMBCS) interventions that will help in the recovery or restoration of the resources at risk.

**On Habitats**

3. Include cost-benefit analysis of restoration of mangroves and protection of corals as part of the OPMBCS.

4. Require economic benefit-cost analysis of all reclamation projects as part of the government approval process.

5. In coming up with land and water use plans as part of the OPMBCS, aim for an appropriate balance between the resources of the bay and economic activities.

6. Implement and enforce strictly the laws and regulations on zoning and Bay use.

7. Support research and development efforts designed to addressing identified data gaps concerning resources and habitats.

**On Shoreline Features**

8. Regulate or reduce extensive land reclamation activities especially real estate development near coastal areas, and enforce strict implementation and compliance to existing land use zoning plans of the coastal municipalities;

9. Intensify mangrove rehabilitation not only to sustain spawning grounds for marine resources (e.g. fisheries and shellfisheries) but also to serve as a natural barriers to shoreline updrift and progradation.

**On Bottom Topography and Bathymetry**

10. Implement proper intervention that will reduce siltation and sediment deposition in the bay resulting from man made activities, particularly agriculture and aquaculture, including continuous denudation of its watershed areas.

11. Enforce strictly rules and regulations regarding ocean dumping of dredged materials and other wastes.

**On Ecological Risks**

12. Prioritize the contaminants for risk management of the ecosystem, i.e.,

Water column: Coliforms > Nutrients (Phosphate) > Pesticides (Heptachlor) > Oil and Grease

Sediment: Heavy Metals (Mercury and Copper) > Heavy Metals (Lead , Zinc, Cadmium, Chromium) > TPAH

13. Set-up properly designed long-term monitoring programs of contaminants especially for coliforms, heavy metals, pesticides, oil and grease, DO, TSS and toxic algae.

14. Establish appropriate Philippine threshold values or PNECs based on scientific data and information; review the criteria for marine waters (DAO 34) especially for heavy metals and TSS.

15. Develop models that can be useful in predicting and validating concentrations of contaminants and their transport.

16. Support initiatives for the gathering of new data on contaminants that potentially present ecological and health risks but for which data are not available at the time of the risk assessment process. This pertains, in particular, to: PAHs, pyrethroids and persistent organic pesticides (POPs), organotins, and substances that exhibit endocrine disruptive effects.

**On Human Health Risks**

17. Identify and prioritize the management of contaminants that pose human health risks i.e., fecal coliforms in shellfish > lead and mercury in fish and shellfish > pesticides (heptachlor and aldrin in fish and endosulfan sulfate in shellfish).

18. Take decisive action regarding the disturbing levels of fecal coliform in the bay by controlling its sources. Short-term solutions include:

    a. Regulate food supply from heavily coliform-contaminated bivalve-growing areas and the use of contaminated beaches and bathing stations; and

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

In the long-term, the following are recommended:

    a. Accelerate sewage collection and treatment programs in highly urbanized and industrialized areas of the Manila Bay area;

    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. Gather secondary data on coliform contamination or coliform loadings for all major tributaries. Use models to determine transport from outfalls and spatial distribution in the bay and to study seasonal effects on coliform levels;

    d. Perform benefit-cost analysis to identify appropriate interventions; and

    e. Provide incentives to proponents of success stories (i.e. sewage treatment facilities).

19. Set-up long-term, properly designed monitoring programs for heavy metals and pesticides in the bay.

20. Establish appropriate local Tolerable Daily Intake values (TDIs) for different age groups.

21. Review existing laws, ordinances and regulations and strengthen enforcement of these by concerned agencies and LGUs. Build technical capabilities of LGU's on law enforcement and in monitoring.

22. Eliminate direct discharges of untreated domestic, industrial, health-care, and agricultural waste, including septic or sludge disposal to Manila Bay and its tributaries.

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

24. Provide safe potable water supply to households.

25. Identify other pathways of human exposure from contaminants of Manila Bay (e.g. skin adsorption, contact with contaminated soil, etc).

26. Implement related research and development projects, particularly on bioremediation measures to reduce the levels of harmful contaminants in the bay and to establish the concentrations of agents in fish and/or shellfish for which there are no data (organotins, POPs, PAHs).

**On Harmful Algal Bloom**

27. Optimize monitoring and management efforts in relation to harmful algal blooms by including:

    a) coordination on the monitoring of environmental parameters in the bay among existing related projects/ programs;
    b) monitoring of the phytoplankton species composition useful in predicting possible harmful algal bloom in key areas (Bataan and Cavite);
    c) monitoring of shellfish for other algal biotoxins;
    d) use of available tools for detection of other algal biotoxins; and
    e) Consideration of risks of getting other harmful algal cells/cyst from ship ballast waters.

28. Ensure proper management of aquaculture farms to control nutrient loading to levels that will not trigger HABs.

# 1. DESCRIPTION OF THE STUDY AREA: MANILA BAY

## 1.1. Introduction

Manila Bay is a valuable resource to more than 16 million Filipinos (NSO, 1996). The GEF/UNDP/IMO 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 for the development and implementation of a Strategic Environmental Management Plan in partnership with the national government and local stakeholders in the public and private sectors.

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 has a shoreline length of 220 km. from a reference point in Mariveles, Bataan with coordinates of $14^o$24'N latitude and $120^o$29'E longitude, to end point in Maragondon, Cavite with coordinates of $14^o$12'N latitude and $120^o$35'E longitude.

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 (NCR).

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 percent, 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 $30^oC$ (PRRP, 1999).

## 1.2. Socio-Economic Significance of Manila Bay

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 chain 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 fish, 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.

Existing land uses of areas along Manila Bay based on Coastal Resources and Land-use Map of Manila Bay (BFAR, 1995) as of 1995 consist of fishponds with a total area of 38,760 ha, which span mostly along the coast of Bulacan, Pampanga and partly along the coastal areas of Bataan. An aquaculture area covered by lahar covers 1,020 ha concentrated in Sasmuan and Lubao, Pampanga in Central Luzon. Fishponds assorted with salt beds with an area of 1,428 ha are found mostly in Cavite area and partly along the coastal areas of Metro Manila. Mudflat and sandy flat covers a total of 4,692 ha found along the coast of Bulacan, Pampanga and Bataan, while mangrove forest including nipa plantation constitutes a total of 794 ha, scattered along the coastal zone of Cavite, Pampanga, and Bulacan, with very small patches in Bataan. Shipping is the major avenue for trade and commerce in the Bay. Approximately 30,000 ships arrive or depart from Manila Bay ports annually transporting goods, raw materials and passengers.

## 1.3. SOURCES OF CONTAMINANTS

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. 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 management program continues to be a serious environmental problem. For example, between 5,000 to 6,000 tons (t) of solid waste are generated daily in Metro Manila. However, only a portion of this waste is being handled at solid waste management facilities. A considerable amount of solid waste is therefore able to enter the bay directly from coastal communities, indirectly from catchments via the river systems, or directly from shipping.

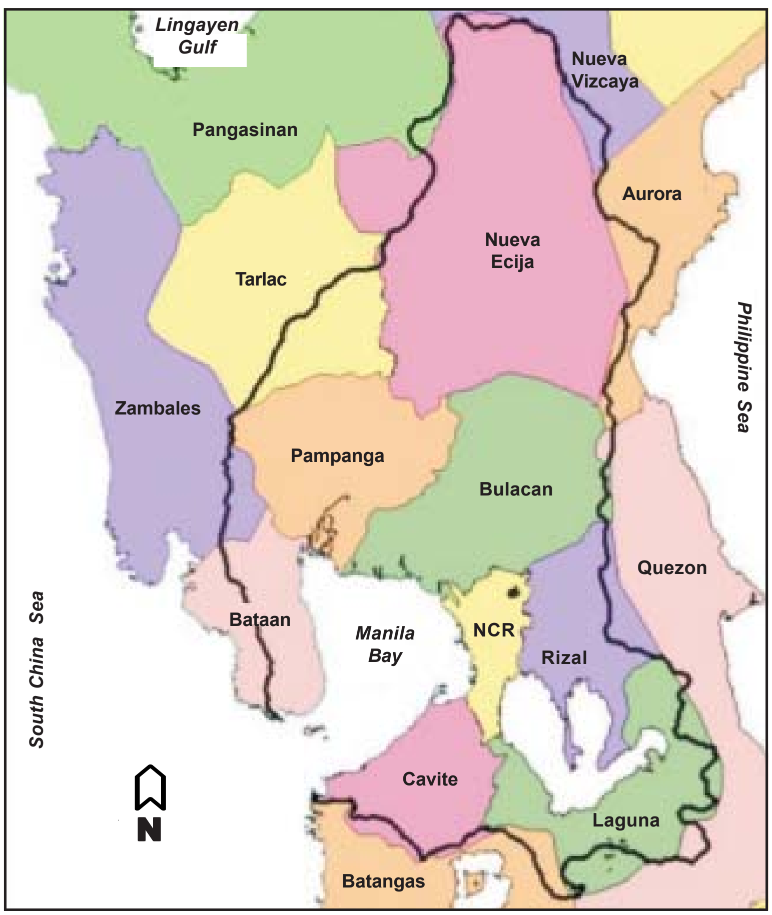
At present, less than seven percent of the population in the 11 major cities and municipalities of Metro Manila, with estimated population of about 8.4 million people [based on the 1995 census (NSO, 1996)], has access to adequate sewerage systems. Thus, about 8 million people in these areas are contributing domestic sewage either directly to the bay or via the river systems (PRRP, 1998). Moreover the existing sewerage collection system connects to an outfall in the bay, with sewage being discharged without treatment. 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 rivers and the bay in general.

## 1.4. AREA COVERED IN THE RISK ASSESSMENT

The initial risk assessment of Manila Bay began with the delineation of the boundaries of the bay as study area. In the refined risk assessment, catchment areas that were not directly along the coast but which ultimately drained into the Bay were also considered to be automatically included. The study area and administrative boundaries are presented in Figure 1.

The study area shown in Figure 1 consists of watersheds draining into Manila Bay through tributaries and major river waterways (area delineated with dark line). It covers the provinces of Cavite, Laguna, Rizal, Bulacan, and Pampanga, Nueva Ecija, and the NCR, and part of the provinces of Bataan and Tarlac. 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 NCR, except for portions of a few municipalities that have waterways that drain into Laguna Lake. 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. One half of the province drains into the bay and the other half into the South China Sea.

**Figure 1. The Administrative Boundaries (LGUs) and Study Area of the Manila Bay Project.**



# 2. 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. Risk assessment 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 MEMP, 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.

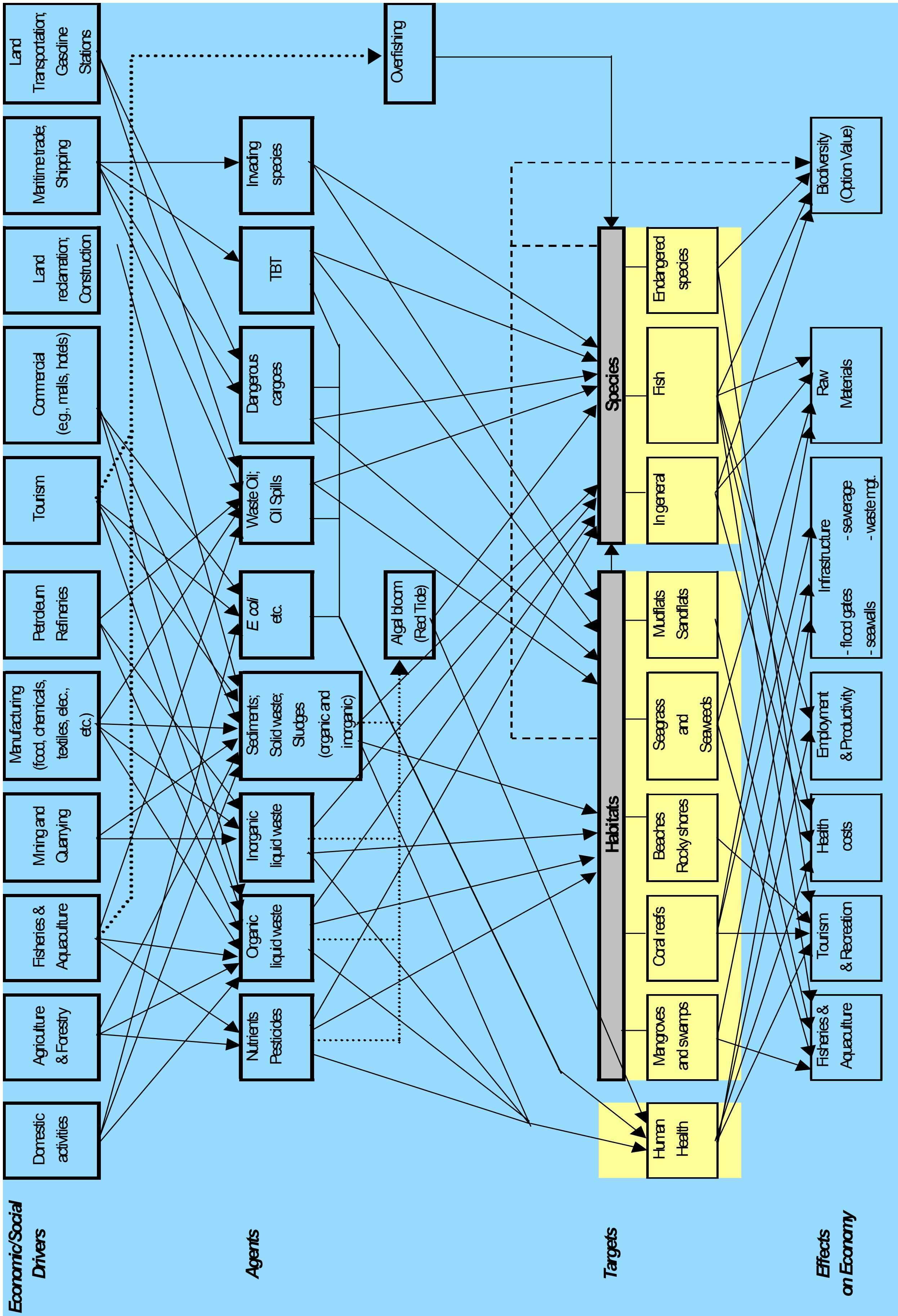
The fundamental features of both retrospective and prospective risk assessment are that they identify problems and their causes based on systematic and transparent principles that can be justified in public and can be revisited as more information and understanding become available. The key concept for 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 an RQ, that is the ratio of an environmental concentration [(either predicted (PEC) or measured (MEC)] with a PNEC for the target of concern [(RQ=P(M)EC/PNEC)]. An $RQ < 1$ indicates a low, and thus acceptable risk, while an $RQ > 1$ indicates a level of concern possibly requiring 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 2) 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.

For ecological risk assessment, the RQ-based prospective risk assessment technique was considered adequate in determining risks posed by contaminants in the water column and sediment. The application of the threshold values or PNECs was based on the following scheme: the local criteria values, i.e., Water Quality Criteria for Coastal and Marine Waters in the Philippines which were initially applied. In the absence

**Figure 2. Simplified Risk Pathways for Manila Bay.**



of local criteria values, the ASEAN Marine Water Quality Criteria (ASEAN, 1999) and criteria values from ASEAN countries were then applied. Subsequently, other tropical jurisdictions, e.g., HK ISQV, were applied. Finally, the criteria values from other jurisdictions, e.g., the United States, were applied.

Water classification according to the Water Quality Criteria for Freshwaters and Coastal and Marine Waters in the Philippines promulgated by the Department of Environment and Natural Resources (DAO 34, series of 1990) are as follows:

### FRESHWATERS (RIVER, LAKES, RESERVOIRS, ETC.)

**Class AA** Public Water Supply Class I. This class is intended primarily for waters having watersheds which are uninhabited and otherwise protected and which require only approved disinfection in order to meet the National Standards for Drinking Water (NSDW) of the Philippines.

**Class A** Public Water Supply Water Class II. For sources of water supply that will require complete treatment (coagulation, sedimentation, filtration, and disinfection) in order to meet the NSDW.

**Class B** Recreational Water Class I. For primary contact recreation such as boating, swimming, skin diving, etc. (particularly those designated for tourism).

**Class C**
1. Fishery water for the propagation and growth of fish and other aquatic resources.
2. Recreational Water Class II (Boating, etc.)
3. Industrial Water Supply Class I. (for manufacturing processes after treatment).

**Class D**
1. For agriculture, irrigation, livestock watering, etc.
2. Industrial Water Supply II (eg. cooling, etc)
3. Other inland waters, by their quality, belong to this classification.

### COASTAL AND MARINE WATERS

**Class SA**
1. Waters suitable for the propagation, survival and harvesting by shellfish for commercial purposes
2. Tourist zones and national marine parks and reserves established under Presidential Proclamation No. 1801 existing laws and /or declared as such by appropriate government agency.
3. Coral reef parks and reserves designated by law and concerned authorities.

**Class SB**
1. Recreational Water Class I (areas regularly used by the Public for bathing; swimming, skin diving, etc.
2. Fishery Water Class I (Spawning areas for Chanos chanos or "bangus" and similar species).

**Class SC**
1. Recreational Water Class II (e.g. boating, etc.).
2. Fishery Water Class II (commercial and sustenance fishing).
3. Marshy and /or mangrove areas declared as fish sanctuaries.

**Class SD**
1. Industrial Water Supply Class II (e.g cooling, etc.).
2. Other coastal and marine waters by, their quality, belong to this classification.

*Source: Revised Water Usage and Classification Water Quality Criteria DENR Administrative Order No. 34 (series of 1990)*

For human health risk assessment, the $RQ^{Geomean}$ and $RQ^{Max}$ were also calculated based on the measured concentrations (geometric mean and maximum concentrations, respectively) in the tissues of fish or shellfish against the TDI adopted from the USFDA divided by the average local consumption rate. Exposure assessment was performed for agents in which the RQ > 1 in order to provide information on the doses actually received by humans from ingestion of seafood.

Finally, the risk-based methodology was applied in the initial and refined risk assessment of Manila Bay as this is viewed to be a reasonable tool in environmental management, particularly when the resources are limited and there is a need to prioritize environmental concerns for risk management. It is recognized, however, that there are other approaches to environmental protection and management. One such approach is based on the precautionary principle, which is explained further in section 4.3.

# 3. RETROSPECTIVE RISK ASSESSMENT

## 3.1. 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.

## 3.2. 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.

### 3.2.1. 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.

### 3.2.2. Identification of Assessment and Measurement Endpoints in the Targets

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 presented in Figure 1 was used.

The suspected agents for the different resources and habitats include: 1) overfishing (overcollection/overharvesting); 2) destructive and illegal fishing; 3) physical disturbance; 4) physical removal/clearance; 5) sedimentation; 6) insect infestation; 7) dissolved oxygen; 8) biochemical oxygen demand (BOD); 9) chemical oxygen demand (COD); 10) nutrients; 11) coliform; 12) toxic algal bloom; 13) heavy metals; 14) pesticides; 15) total suspended solids (TSS); 16) total organic carbon (TOC); 17) oil and grease; 18) polyaromatic hydrocarbons (PAHs); 18) polychlorinated biphenyls (PCBs) and other organics; and 19) oil spills.

The identified targets for resources included: 1) fisheries; 2) shellfisheries; 3) seaweed and benthos; and 4) phytoplankton. The identified targets for habitats were: 1) mangroves; 2) coral reefs; 3) seagrass beds; and 4) soft-bottoms, mudflats, sandflats, beaches, and rocky shores.

In addition, changes in the physical features of the bay particularly bathymetric and shoreline changes, and their concomitant effects on habitats and resources, were also examined.

### 3.2.3. Determination of Likelihood of Harm on the Identified Target by the Suspected Agent

Under the retrospective risk assessment phase, a set of questions, answerable by yes (Y), no (N), maybe (M), don't know (DK), or no data (ND) was formulated in order to establish evidence of decline and the causes and consequences of the decline. The following questions were adapted from the Environmental Risk Assessment Manual (MPP-EAS, 1999a).

- Is the target exposed to any of the agents?
- Was there any loss/es that occurred following exposure? Was there any loss/es correlated through space?
- Does the exposure concentration exceed the threshold where adverse effect starts to happen?
- Do the results from controlled exposure in field experiments lead to the same effect? Will removal of the agent lead to amelioration?
- Is there specific evidence in the target as a result of exposure to the agent?
- Does it make sense (logically and scientifically)?

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 by assigning the likelihood of these agents to have caused the decline in resources and habitats. Deciding the likelihood based on the answers to the decision table was aided by the decision criteria as presented in Appendix 5.

The different categories of likelihood of harm are as follows:

1. Likely - 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 - 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 - 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 - 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.

The resulting summaries of the likelihood of agents to have caused the decline in resources and habitats are presented in Appendix 1 and were 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.

The results of the retrospective analysis of each resource or habitat (identified target) in terms of areal extent, changes observed and the identified agents for these changes, and the ecological and socio-economic consequences of these changes is summarized in a tabulated form for each resource or habitat assessed.

## 3.3. RESOURCES

### 3.3.1. Fisheries

#### 3.3.1.1. 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.

CPUE is the number or weight of fish caught by a unit of fishing effort, e.g., weight in kilograms (kg)/hour of fishing. It is often used as a measure of fish abundance or fishing gear efficiency. The trend in CPUE of trawl, a widely used fishing gear in the bay, clearly indicates that there is a decline in the Manila Bay demersal fisheries (Table 2). The CPUE decreased dramatically in 1957 to nearly one-third of its value in 1947, i.e., from 44 kg/hour to 16.2 kg/hour. In 1970, the CPUE increased to 61.8 kg/hour with the introduction of more efficient trawl gears and high-opening trawlers. However, due to overfishing, the CPUE steadily declined thereafter up to 10 kg/hour in 1993. Table 2 likewise shows increase of relative abundance of invertebrates and decrease of fish through time.

With the application of the Schaeffer and Fox surplus production models on the set of trawl fisheries data (Figure 3), the maximum sustainable

## Table 1. Retrospective Analysis for Fisheries in Manila Bay.

| Resource Type | Areal Extent | Results: Change/s Observed | Results: Identified Agent/s | Impact |
|---|---|---|---|---|
| Fisheries | Large (entire Manila Bay) | Quantity:<br>• Decline in trawl CPUE (kg/hr) : 44 to 12.2 (1947-1959); 61.8 to 27.9 (1970-1983); 14 to 10 (1986-1993)<br>• Decline in demersal biomass: 4.61 mt/km$^2$ or 8,290 tons to 0.47 mt/km$^2$ or 840 tons (1947-1993)<br>• Exploitation of demersal fisheries is beyond the bay's MSY<br>• Increase in number of fishers per km of coastline: 70 to 253 (1987-1993)<br>• Increase in number of boats per km coastline: 74 (1980), 95 (1991), 105 (1993)<br>• Relatively low length at infinity<br>• High exploitation rates of commercially important species<br><br>Quality:<br>• Change in trawl catch composition from economically valuable to less valuable species (1947 - 1993)<br>• Decrease in the relative abundance of finfish and increase of invertebrates of the demersal fisheries<br>• Increase in the relative abundance of pelagic species in the demersal trawl catch<br>• Disappearance/near absence of some species (e.g. lizard fish and flat fish)<br>▪ Disappearance of larger individuals<br>▪ Dominance of immature individuals | Likely:<br>• Growth overfishing<br>- increase in the number of fishers and boats<br>- use of very efficient gears<br>- use of destructive fishing (small mesh nets, dynamite fishing)<br>• Recruitment overfishing<br>- reduction of spawning parent stock<br>- destruction of habitats reducing the quality and size of nursery areas<br><br>Possibly:<br>• Low DO<br>• Heavy metals<br>• Total suspended solids<br>• Pesticides<br>• Oil and grease<br>• Nutrient load<br><br>Unlikely:<br>• Lahar flow<br>• Solid waste, especially plastic materials<br><br>Unknown<br>• Precipitate from air pollutants | • Fish are caught before they have a chance to grow<br>• Reduced demersal fishery production<br>• Increased production from pelagic fisheries<br>• MSY from demersal stock has been exceeded and it will be difficult to reverse the situation<br>• Less production of eggs and larvae<br>• Low natural survival of eggs and larvae<br>• Change in species population structure<br>• Loss of economically important species<br>• Reduced economic value due to decrease in average sizes of fish<br>• Continuous modification of gears with increased efficiency to catch remaining/ existing dominant species |

*Sources: BFAR, 1995.*

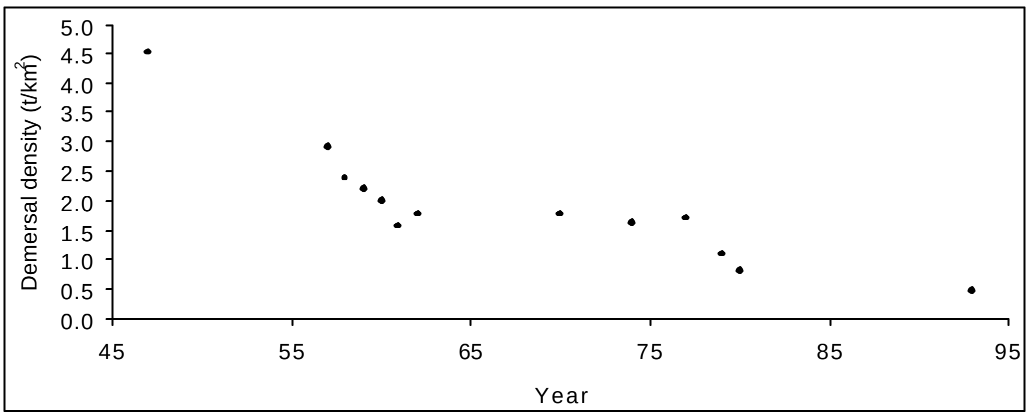
## Table 2. Compilation of Information from Different Trawl Surveys in Manila Bay.

| Year | CPUE (kg/hr) | Composition (%) | | Year | CPUE (kg/hr) | Composition (%) | |
|---|---|---|---|---|---|---|---|
| | | Fish | Invertebrates | | | Fish | Invertebrates |
| 1947 | 44.0 | | | 1962 | 16.3 | 91 | 8 |
| 1948 | 45.8 | | | 1966 | 14.0 | | |
| 1957 | 16.2 | | | 1970 | 61.8 | | |
| 1958 | 13.3 | 81 | 19 | 1971 | 37.4 | | |
| 1959 | 12.2 | | | 1983 | 27.9 | 80 | 20 |
| 1960 | 15.7 | 96 | 4 | 1986 | 14.0 | 36 | 64 |
| 1961 | 13.6 | | | 1993 | 10.0 | 75 | 25 |

*Sources: BFAR, 1995.*

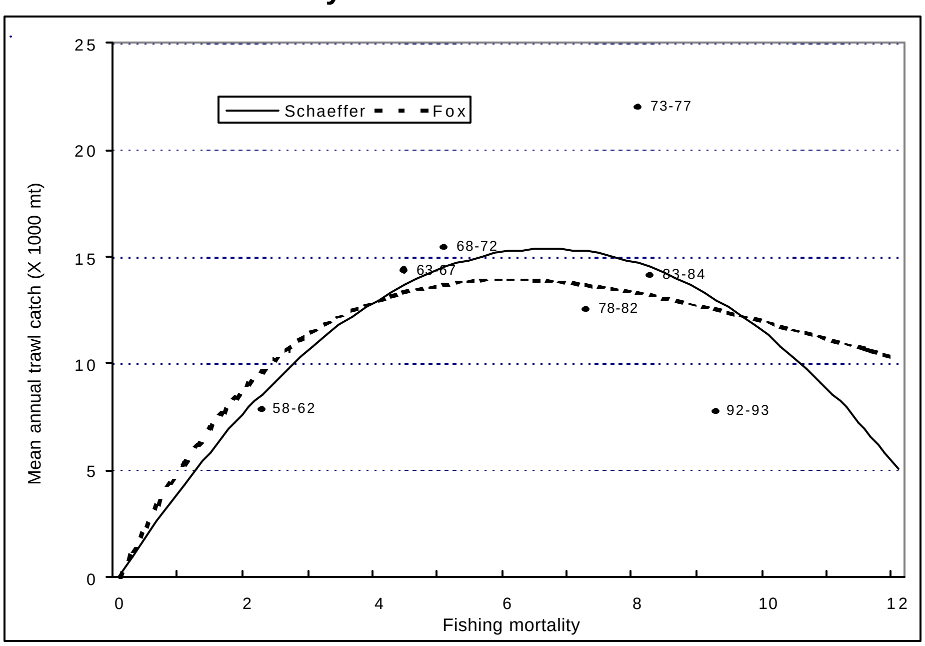
yield (MSY) for demersal catch was computed. Surplus production models involve the use of "surplus production", which is the production of new weight by a fishable stock, plus recruits added to it, less what is removed by natural mortality. This is usually estimated as the catch in a given year plus the increase in stock size (or less the decrease). The results of both models (Figure 4) show that the maximum sustainable yield for demersal catch is around 15,000 metric tons (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. The high fishing pressure and ensuing high production in mid 1970s resulted in a significant decrease in average annual yield in the late 1970s and early 1980s.

**Figure 3. Scatter Diagram of Demersal Biomass Density (t/km²) Estimated from Different Trawl Surveys of Manila Bay Conducted from 1947 to 1993.**



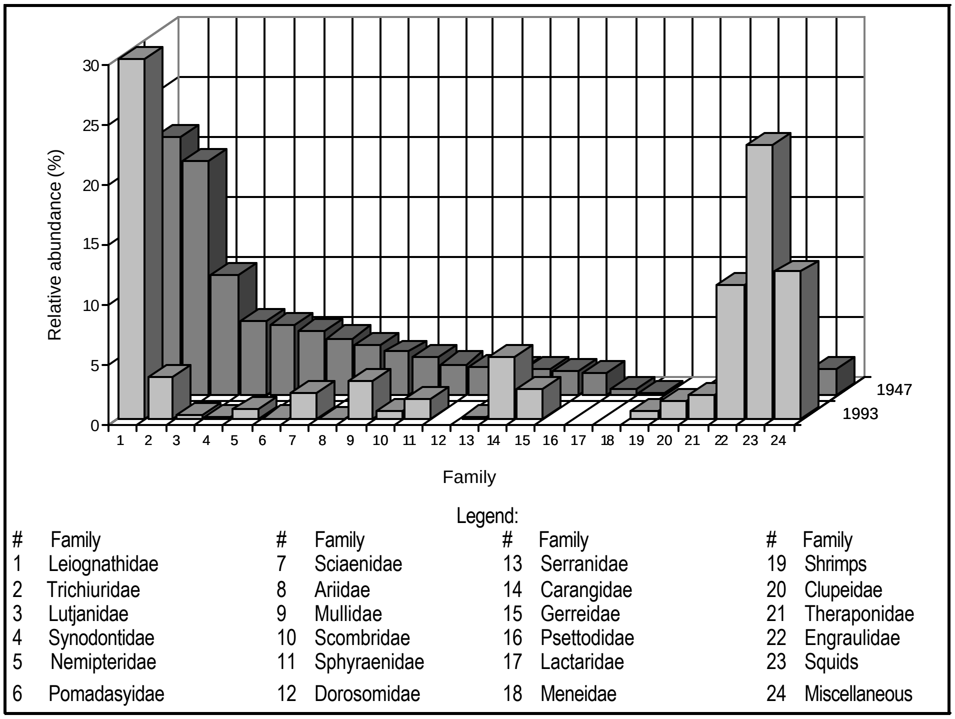

*Sources: Modified from Armada, 2001*

**Figure 4. Schaffer and Fox Surplus Production Models Applied to Manila Bay Demersal Trawlable Stock.**




*Sources: BFAR, 1995.*

**Figure 5. Catch Composition, Grouped into Families, Obtained from Two Trawl Surveys of Manila Bay Conducted in 1947 and 1993.**




*Sources: BFAR, 1995.*

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 relative abundance of demersal invertebrates. Major changes noted in catch composition include increase in the relative 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 (Figure 5).

One particular species, the kalaso or common lizard fish (*Saurida tumbil*), used to be caught in large numbers in the past, are now very few and, if ever caught, are usually small in size. Although the increase in the relative abundance of shrimps may have some positive economic impact to trawl operators, the long term biological and economic effects of the continuous change in population structure will be negative especially to small-scale fishers.

Other quantified evidences of fisheries decline observed were the relatively low length at infinity ($L_\infty$) and relatively high exploitation rates (E) of abundant species (Table 3). Fish were caught so fast that most are no longer given a chance to reach their optimum lengths. Most fish species have been continuously subjected to high fishing mortality rates or high exploitation rates.

**Table 3. Summary of Growth and Mortality Parameters of Selected Species Caught in Manila Bay between November 1992 to October 1993 Estimated via ELEFAN.**

| Species | $L_\infty$ | K | Z | M | F | E |
|---|---|---|---|---|---|---|
| *Atule mate* | 27.0 | 0.70 | 5.30 | 1.48 | 3.82 | 0.72 |
| *Gerres fialmentosus* | 18.3 | 0.90 | 5.34 | 1.95 | 3.39 | 0.63 |
| *Leiognathus bindus* | 10.5 | 1.10 | 4.97 | 2.59 | 2.38 | 0.48 |
| *Nematalosa nasus* | 25.0 | 1.15 | 3.47 | 2.09 | 1.38 | 0.40 |
| *Nemipterus japonicus* | 25.5 | 0.90 | 3.49 | 1.77 | 1.72 | 0.40 |
| *Stolephorus commersoni* | 13.0 | 0.95 | 4.04 | 2.22 | 1.82 | 0.45 |
| *Sardinela fimbriata* | 16.5 | 0.80 | 3.60 | 1.85 | 1.75 | 0.49 |
| *Secutor insidiator* | 12.5 | 1.00 | 5.01 | 2.32 | 2.69 | 0.54 |
| *Selaroides leptolepis* | 25.5 | 0.95 | 3.26 | 1.84 | 1.42 | 0.44 |
| *Sillago sihama* | 25.5 | 0.75 | 4.68 | 1.57 | 3.11 | 0.66 |
| *Trichiurus haumela* | 90.0 | 0.70 | 3.52 | 1.06 | 2.46 | 0.70 |
| *Thryssa setirostris* | 17.5 | 1.10 | 6.14 | 2.25 | 3.89 | 0.63 |
| *Upeneus sulphureus* | 17.0 | 1.00 | 6.50 | 2.13 | 4.37 | 0.67 |
| *Valamugil seheli* | 23.0 | 1.00 | 6.83 | 1.96 | 4.87 | 0.71 |

*Sources: BFAR, 1995.*

Using the collected length frequency data, growth parameters ($L_\infty$, K) of the von Bertalanffy equation: total (Z), natural (M) and fishing (F) mortalities; the exploitation ratio (E); and recruitment patterns of dominant and economically important species were estimated via ELEFAN (Electronic Length Frequency Analysis). The following basic equations were applied:

$$L_t = L_\infty\ [1 - e^{-k(t - t_0)}]$$

where:
- $L_t$ = length of fish at age t
- $L_{00}$ = asymptotic length of the mean size at which the fish would grow if they were allowed to live and grow indefinitely
- e = base of Naperian logarithm
- k = growth coefficient
- $t_0$ = hypothetical age the fish would attain at length zero, if it has always grown in a manner as described by the von Bertalanffy equation

$$N_t = N_0 e^{-Zt}$$

where:
- $N_t$ = number of surviving fishes in the population or cohort at time t
- $N_0$ = initial number of fishes in the cohort or population at time t = 0
- $Z_t$ = total instantaneous mortality coefficient

$$Z = M + F$$

where:
- Z = total instantaneous mortality
- M = exponential rate of natural mortality or death caused by predation, old age, pollution, etc.
- F = exponential rate of fishing mortality or death caused by fishing

$$E = F/Z$$

where:
- E = exploitation
- F = fishing mortality
- Z = total mortality

Due to excessive fishing and the eventual decline in mature fish population, some individuals are unable to complete their life cycle, from juvenile stage to maturity, with more being caught still at the juvenile and immature stages (Table 4). This is especially true for demersal species but to a lesser degree to pelagic species. Thus, there was an observed small and/or reduced size (length) of fish caught. Fishing pressure 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.

There are two types of fishing operations in Manila Bay. The commercial fisheries as defined in the Philippine Fisheries decree of 1975 (PD 704) include fishing operations that use vessels of over three gross tons (GT), including vessels that do not involve the use of watercraft. Small municipal fishing has an average tonnage of 0.40 GT.

The main fishing grounds in Manila Bay are in particular, the areas fronting Bataan and Cavite. The average distance travelled for all gear types is 32 km especially for fishers using bag nets and ring nets, and 11 km for non-motorized bancas. (Gacutan et al., 1996)

Aquaculture is considered as ecologically advantageous because it increases fish yield and decreases fishing pressure in coastal areas. Fishpond development, on the other hand, is considered as an environmentally critical project as this may create negative impacts to the environment, especially water pollution, if not properly planned and managed.

**Table 4. Relative Frequency Distribution (%) of Selected Species by Stages of Maturity.**

| Species | Juvenile | I | II | III | IV |
|---|---|---|---|---|---|
| *Atule mate* | 55 | 16 | 19 | 8 | 2 |
| *Caranx malabaricus* | 92 | 8 | 0 | 0 | 0 |
| *Gerres filamentosus* | 10 | 11 | 37 | 39 | 2 |
| *Gazza minuta* | 21 | 16 | 47 | 17 | 0 |
| *Leiognathus bindus* | 34 | 22 | 23 | 20 | 1 |
| *Nematalosa nasus* | 11 | 20 | 18 | 46 | 6 |
| *Nemipterus japonicus* | 16 | 24 | 32 | 27 | 0 |
| *Sardinella fimbriata* | 23 | 11 | 8 | 52 | 6 |
| *Saurida tumbil* | 59 | 29 | 12 | 0 | 0 |
| *Secutor insidiator* | 17 | 20 | 17 | 41 | 5 |
| *Selaroides leptolepis* | 8 | 0 | 10 | 38 | 45 |
| *Sillago sihama* | 0 | 0 | 16 | 73 | 11 |
| *Stolephorus commersonii* | 4 | 0 | 29 | 67 | 0 |
| *Thryssa setirostris* | 0 | 21 | 15 | 56 | 7 |
| *Trichiurus haumela* | 54 | 22 | 12 | 10 | 2 |
| *Upeneus sulphureus* | 62 | 19 | 19 | 0 | 0 |
| *Valamugil seheli* | 6 | 26 | 42 | 23 | 3 |

*Sources: BFAR, 1995.*

*Note: Stage I: Immature, Virgin*
*Stage II: Developing/maturing*
*Stage III: Matured/developed*
*Stage IV: Gravid and Spawning*

One of the most important fishery products of the Philippines is milkfish because of its popularity as a food item in the Filipino diet. The cost-benefit analysis for milkfish culture prepared by DENR-in 1997 suggests a net income of PhP 115,939.50. This income is derived with an initial 60,000 pieces of bangus fry and with annual production cost of PhP 168,330.50. This number of fry can produce about 4,061 kg of fish harvest within the year. The details of the analysis are shown below.

**Cost return analysis of culturing milkfish**

| Item | Value (in peso) | Total value (in peso) |
|---|---|---|
| **Annual revenue** | | 284,270.00 |
| Sale 4,061 kg @ P70/kg | | |
| **Annual production cost** | | 168,330.00 |
| Fry 60,000 pcs @ P0.50 | 30,000.00 | |
| Supplemental Feeds | | |
| Artificial pellets | | |
| 5,000 kg @ P12.00/kg | 60,000.00 | |
| Bread crumbs | | |
| 300 kg @ P8.00 | 2,400.00 | |
| Lime 500 kg @ P2.00 | 1,000.00 | |
| Fertilizers | | |
| Chicken manure | | |
| 6 tons @ P800.00 | 4,800.00 | |
| 46-0-0 1.5 bags @ P260.00 | 390.00 | |
| 16-20-0 4.5 bags @ P320.00 | 1,440.00 | |
| 21-0-03 bags @ P190.00 | 570.00 | |
| Electricity 300 kwh @ P3.00 | 900.00 | |
| Labor | | |
| 1 caretaker P3,000/mo @ 12 | 36,000.00 | |
| 1 laborer P2,400/mo @ 12 | 28,800.00 | |
| Marketing expense | | |
| (4,061 kg @ P0.50/kg) | 2,030.00 | |
| **Fixed investment** | | 32,800.00 |
| 1 Unit culvert | | |
| Drain date @ P30,000 | 30,000.00 | |
| Cost of labor for pond | 2,800.00 | |
| Improvement (4 laborers @ | | |
| 100/day x 7 days) | | |
| **Net return** | | 115,939.50 |
| Annual revenue | 284,270.00 | |
| Less: Annual production cost | 168,330.50 | |
| **Return on fixed investment** | | 3.53 |
| Net return | 115,939.50 | |
| Fixed investment | 32,800.00 | |
| **Return on total investment** | | **0.58** |
| Net return | 115,939.50 | |
| Fixed investment + production cost | 201,130.50 | |
| Assumption: Pond is already existing. It only needs minimal improvement, 95% survival rate. | | |

*Source: DENR.1997 Info Kit*

**Table 5. Municipal Fisheries Production Data in Manila Bay (metric tons).**

| Year | Region III | | | Total | Region IV | NCR | Grand Total |
|---|---|---|---|---|---|---|---|
| | Bataan | Bulacan | Pampanga | | Cavite | | |
| 1980 | 3,965 | 2,640 | - | 6,605 | 2,913 | 5,0701 | 4,588 |
| 1981 | 4,684 | 2,000 | - | 6,684 | 5,136 | 6,401 | 18,221 |
| 1982 | 5,398 | 2,026 | - | 7,424 | 3,548 | 7,831 | 18,803 |
| 1983 | 4,633 | 2,046 | - | 6,679 | 3,473 | 7,272 | 17,424 |
| 1984 | 5,019 | 2,067 | - | 7,086 | 3,917 | 7,529 | 18,532 |
| 1985 | 6,597 | 2,604 | - | 9,201 | 4,331 | 5,806 | 19,338 |
| 1986 | 4,672 | 2,714 | - | 7,386 | 2,834 | 6,314 | 16,534 |
| 1987 | 5,354 | 2,443 | - | 7,797 | 2,992 | 9,569 | 20,358 |
| 1988 | 4,358 | 2,569 | - | 6,927 | 2,398 | 8,095 | 17,420 |
| 1989 | 4,941 | 2,909 | - | 7,850 | 2,672 | 8,554 | 19,076 |
| 1990 | 5,860 | 3,032 | 436 | 9,328 | 3,018 | 9,782 | 22,128 |
| 1991 | 4,496 | 2,753 | 345 | 8,594 | 2,623 | 9,592 | 20,809 |
| 1992 | 3,248 | 2,214 | 501 | 5,963 | 2,602 | 9,033 | 17,598 |
| 1993 | 1,950 | 1,162 | 561 | 3,673 | 2,253 | 7,315 | 13,241 |
| 1994 | 3,630 | 1,061 | 632 | 5,323 | 2,003 | 5,421 | 12,747 |
| 1995 | 2,900 | 1,067 | 668 | 4,635 | 2,486 | 4,528 | 11,649 |
| 1996 | 2,917 | 647 | 812 | 4,376 | 2,330 | 3,665 | 10,371 |
| 1997 | 2,834 | 672 | 908 | 4,414 | 2,336 | 3,529 | 10,279 |
| 1998 | 4,282 | 927 | 987 | 6,196 | 1,827 | 4,604 | 12,627 |
| 1999 | 5,010 | 695 | 1,041 | 6,746 | 1,572 | 4,156 | 12,474 |
| 2000 | 5,283 | 758 | 1,100 | 7,141 | 1,494 | 3,982 | 12,617 |

*Source: Bureau of Agricultural Statistics, Fisheries Statistics of the Philippines 2000.*

The total municipal fish production in Manila Bay from 1980 to 2000 (Table 5) shows an increasing trend from 14,588 mt to 20,358 mt. Peak production was recorded in 1990 followed by a steady decline thereafter.

Fish production in the NCR III registered higher harvest compared to Region IV from 1990 to year 2000. The peak production was recorded in 1990 at 9,782 mt for NCR and 9,328 mt for Region III. (Table 5).

#### 3.3.1.2. Attributed causes of the decline

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 in 1987 to 253 in 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 (220 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) 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.

Extreme fishing pressure can lead to two forms of overfishing, namely, growth and recruitment overfishing. Growth overfishing occurs when fish are caught before they have a chance to grow and it is caused by extremely high fishing effort and use of inappropriate mesh size. In Manila Bay, fishing gears like trawls and push nets are known to catch relatively small fish (Table 6). For the same targets species, their catch are composed of relatively small individuals compared to those caught by different hook and lines and gillnets.

Recruitment overfishing, on the other hand, occurs when so few adult fish are left in a given exploited stock that the production and natural survival of eggs and larvae is reduced to the extent that recruitment to the fishery is impaired. This is caused by both the reduction of the spawning stock which may result to production of limited number of eggs and larvae and coastal environmental degradation which usually affects the quality and size of the nursery areas. All of these have already occurred in Manila Bay.

Socio-economic considerations can also have a bearing on the density of fish resources in Manila Bay. As stressed in the implementing rules and policies for management and conservation of the fisheries and aquatic resources of the Philippines, all users of municipal waters are authorized or permitted to operate within 10.1-15 km from the shoreline. The number of municipal fishermen compared to commercial fishermen is higher such that most fishermen are concentrated in the zone between 4-20 km from the shore. Close competition for higher yield in the fishing areas will result to overfishing and lead to decline in fish resources. Enforcement of laws and regulations is costly. This is the problem encountered for management of commercial and municipal fishing in the Philippines, especially in the case of tuna fishing (Arce, 1988).

The fishing effort for small pelagics in the Philippines greatly exceeds the level of effort to attain the MSY according to Dalzell et al., 1987. This is also a problem related to the decline of fish resources in the Philippines.

The effects of other pollutants such as heavy metals, pesticides, oil and grease, and high TSS on the fisheries could not be totally excluded and, in varying levels and actions, may have contributed to the observed decline in standing biomass. Likewise, nutrient load from the various river systems at the onset of rainy season may initially

**Table 6. Average Individual Lengths (cm) of 10 Selected Species Caught by Different Fishing Gears in Manila Bay.**

| Species | Long Line | Hook and Line | Liftnet | Drift Gillnet | Bottom Set Gillnet | Push Net | Trawl |
|---|---|---|---|---|---|---|---|
| *Atule mate* | 15.5 | 17.4 | 14.0 | 15.7 | 14.3 | | 9.7 |
| *Gerres filamentosus* | | | | 9.1 | 10.0 | 9.6 | 7.9 |
| *Nematalosa nasus* | | | | 14.5 | 10.7 | 9.2 | 10.3 |
| *Nemipterus japonicus* | | 14.3 | 15.2 | 15.7 | 14.1 | 12.8 | 12.3 |
| *Sardinella fimbriata* | | | 11.3 | 12.5 | | 7.0 | 9.4 |
| *Selaroides leptolepis* | 13.9 | | 11.5 | 16.0 | 15.1 | | 7.0 |
| *Sillago sihama* | 15.2 | 15.1 | | 13.4 | 15.0 | 13.4 | 13.5 |
| *Thryssa setirostris* | | | 11.3 | 11.7 | 11.8 | | 7.7 |
| *Trichiurus haumela* | 56.9 | | | 58.0 | 53.4 | | 23.7 |
| *Valamugil seheli* | | 12.0 | 12.7 | 12.8 | 12.2 | | 12.9 |

*Source:BFAR, 1995.*

appear to nourish phytoplankton and algae but may exacerbate the resource decline through eutrophication and enhancement of harmful algal bloom (HAB). Lahar flow from the Pampanga River may increase TSS quantity locally and destroy substrate communities along the Pampanga delta. The presence of solid wastes, especially plastic wrappers, are also harmful to aquatic organisms. Occurrence of plastic wrappers is especially high along the nearshores of the Metro Manila. Lahar flow and presence of solid wastes, are however very localized and are thus considered unlikely to have caused the decline of fisheries to the extent observed. Precipitate from air pollution was never quantified but it is likely to settle on the seawater surface.

Results of water quality analysis for Manila Bay by the National Pollution Control Commission (now Environmental Management Bureau) have shown that bacterial count (1982-1985 data) along the coast ranged from three to even a hundred times greater than the standard set for class SB (marine and estuarine waters used for primary contact recreation). DO values obtained generally conformed to the 5 mg/L criterion for class SB except in some areas especially Pasig River. Sedimentation rate (1984 data) is relatively high compared to the figures obtained in other areas like San Miguel Bay in Bicol Region. (UNEP - EMB 1991).

EMB also reported that the concentrations of trace metals such as Cu, Pb and Cd have been noted to exceed the criteria set for water bodies for propagation and growth of fishes and other aquatic resources. The concerted efforts of EMB-UNEP to monitor the water quality of Manila Bay as well as rivers have justified the need to protect the resources from further degradation and maintain water quality.

The Meycauyan River System is composed of seven tributaries which originate from the hills of Sapang Palay and San Jose del Monte and courses down into Manila Bay. Tuazon and Ancheta in 1992 reported that the upper reaches of the river system, from the head waters until San Jose del Monte, are freshwater and still relatively unpolluted. The lower reaches especially Balagtas, Guiguinto, and Bulacan River are heavily polluted.

They reported that the main polluters of the Meycauyan river system are poultries, piggeries, duck farms and cattle feed lots, varying in size of operation from commercial scale to backyard pen. In Sta. Maria alone, over two million chickens are produced annually and about half as many hogs. The amount of organic wastes being discharged by these animals into the rivers is substantial since a thousand pounds of chicken produce 59 lbs of manure daily with BOD of 4.4 lbs/day.

Another source of pollution into the major river of Bulacan is brought by other agricultural activities. Application of herbicides, fertilizers, and insecticides is both intensive and extensive in Bulacan because agriculture is the province's primary economic activity. Although these chemicals are widely used, gas chromatographic analysis of water and fish samples from the river systems and the Manila Bay indicate that these persistent chemicals have not yet exceeded tolerable levels in the rivers. Herbicides used on agricultural crops can contaminate ponds. Even though these materials may not be appreciably toxic to aquatic animals they may harm phytoplankton. For example, Tucker (1987) as mentioned by Boyd and Frobish (1990), demonstrated that the herbicide propanil [N-(3-4-dichlorophenyl) propanamide] which is sprayed on rice fields for weed control, reduces oxygen production by phytoplankton communities.

Modern practices and technological innovations intensify agricultural production by farms in the Manila Bay Region. In Central Luzon, Torres *et al.* in 1994 conducted a monitoring study of ground water quality in selected farming areas and reported that contaminants like nitrate is within tolerable limit and found no pesticides in the ground water. According to Edwards (1920) as cited by Torres *et al.* (1994), pesticide contamination is much greater for surface water than for ground water. Pesticide with higher molecular weights such as chlorinated hydrocarbons, generally have low water solubility and are absorbed by clay and organic matter in the soil and can be carried down to streams by surface run-off from treated fields. Although there is no study on the pattern of streaming for pesticide residues towards Manila Bay, it is said to be one of the attributed causes of water contamination in Manila Bay.

Nitrogen loading from aquaculture farms is not only toxic to the fish but also stimulate eutrophication. Nutrient loading from fish cages enter marine waters in the form of nitrate, ammonia, total organic nitrogen or total nitrogen (Saynor, 1996). The Manila Bay coastal zone has approximately 33,853 ha of fishpond area as of 1995. Problems arise because of the large volumes of water discharged from intensive farms compounded by the high density of farm units in areas with limited water supply and inadequate flushing.

Intensive aquaculture practices pose further damaging effects to the fishery resources with the use of chemical and biological products to solve the self-polluting characteristics of intensive ponds. These products include therapeutants and disinfectants and conditioners, bacteria-enzyme preparations, algicides and piscicides, plankton growth promoters and feed additives (Primavera, *et al.*, 1993). Chemical and biological pollution by shrimp farms results from disposal into coastal waters of pond effluents and sludge, misuse of antibiotics and other chemicals, and introduction of exotic shrimp species and diseases (Primavera 1998, Naylor *et al.*, 1998).

#### 3.3.1.3. Consequences of the Decline in Fisheries

Growth and recruitment overfishing can further lead to ecosystem and economic overfishing. Ecosystem overfishing happens when the decline (due to excessive fishing) in the multi-species stock is not fully compensated for by the rise in the other exploitable animals. This is evidenced by the change in species composition and decrease of average sizes through time. Subsequently, this results to economic overfishing. This happens when less than maximum economic yield is obtained from the fishery. In Manila Bay, overfishing has led to reduced fish biodiversity (e.g. relative decrease in the finfish population and a relative increase in invertebrate population of the demersal fish), loss of economically important species, decreased average sizes, reduced fish yield, and the consequent economic and social losses.

As mentioned above, the increase in the relative abundance of shrimps may have some positive economic impact to trawl operators but the long term biological and economic effect of the continuous change in population structure will be negative to finfish fishermen especially to small-scale hook and line and gill net fishers. The use of simple fishing gears is no longer effective. Fisherfolks, particularly those who depend on subsistence fishing are therefore economically and socially disadvantaged.

BFAR (1995) shows that the current demersal biomass density of Manila Bay is very low near the coastline and increases towards the deeper portion. It is highest between Corregidor and Bataan. This profile reflects the different levels of utilization, fishing and others, of different sections of the bay. Obviously, the negative impact of built-up areas to the marine resource base is reflected. The demersal biomass density are likewise low along fishpond areas.

Conversion of mangroves into brackishwater ponds is one of the development activities which create disturbance on the mangrove ecosystem. (Jara *et al.*, 1989). It is also the principal factor behind the loss of Philippine mangrove forest (Zamora, 1990). The continuous conversion of mangrove areas for aquaculture purposes also includes those areas within the mangrove forest reserves. The development of mangroves into fishponds and its management and conservation as fishing resources is covered in the Philippine Fisheries Code of 1998 (RA No. 8550). Fishponds are leased to qualified persons and fisherfolk organizations and are subject to many conditions. In Chapter VI Section 102 of RA 8550, management of aquaculture farm wastes and contaminants, including chemical and biological pollutants, are addressed.

### 3.3.2. Shellfisheries

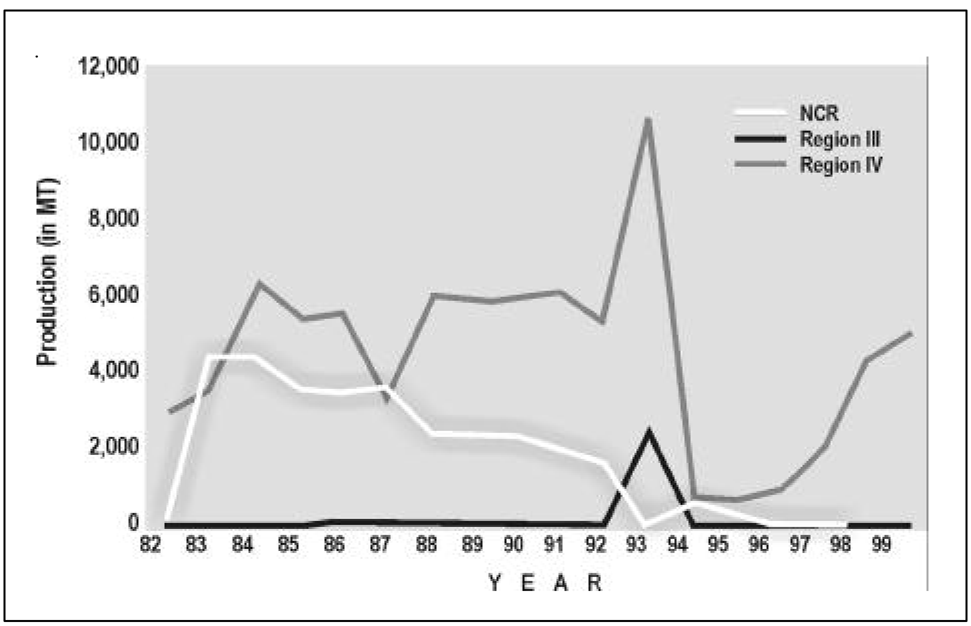
#### 3.3.2.1. Evidence for Decline in Shellfisheries

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*.

Figures 6 and 7 show production of mussels and oysters, respectively, during the period 1982 to 1999 from the Bureau of Fisheries and Aquatic Resources (BFAR) records. The data for Region IV showed increased production from 1983 to 1984 for mussels followed by decreasing trends from 1984 to 1988. There was a short peak in 1993 and a drastic decline thereafter. Mussel production slowly increased from 1995 and reached almost half the 1993 peak production (Figure 6). For the NCR, highest production was recorded in 1983 followed by steady decline, peaking slightly in 1994 before declining again. For Region III, production was consistently low compared to the two other areas, with a sharp peak in 1993 and subsequent decline.

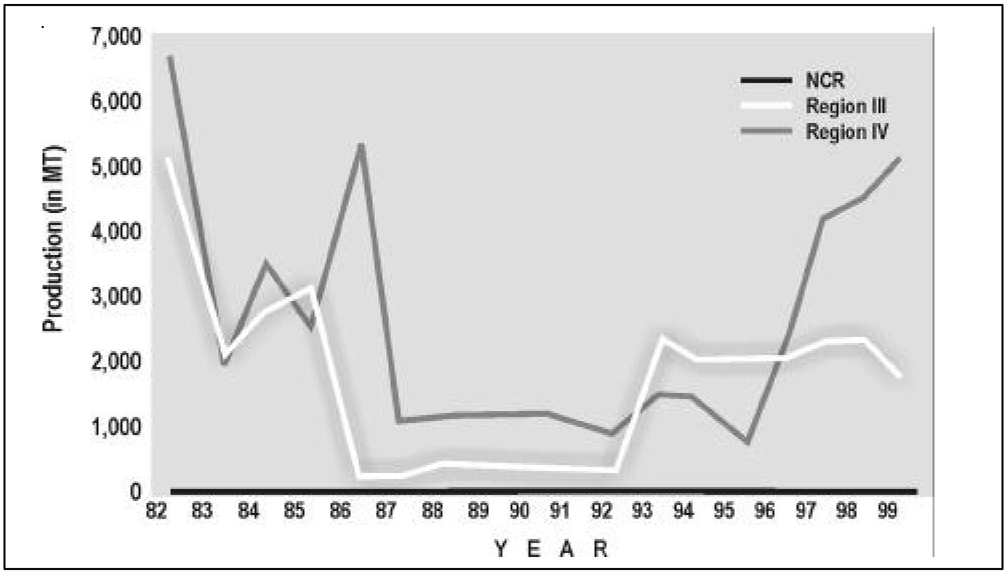
On the other hand, there was a sharp decrease in oyster production between 1982 and 1983 (Figure 7). The production slightly increased in 1984 and sharply declined in 1986 for Region III while production peaked for Region IV in 1986 followed by sharp decline in 1987. For both regions, there was low oyster production until 1992. There was a short peak in 1993 before steadily increasing to 1999. Oyster production at the NCR was low and not of the same scale as the production in Regions III and IV.

**Figure 6. Mussel Production in Manila Bay, 1982-1999.**




*Source: BFAR, 2000.*

**Figure 7. Oyster Production in Manila Bay, 1982-1999.**




*Source: BFAR, 2000.*

Based on the coastal resources and land use map of Manila Bay (Sept. 1993) (BFAR, 1995), shellfish farms, which often thrive well in mudflat areas, can be found off the coast of Bataan, in the western side of the bay from Orion to Orani. They can also be found in mudflat areas in Pampanga Bay in the northeastern side of the bay, and off the coast of Bulacan to Malabon (north to northeastern side of the bay). Other cultured species are crabs and prawns, especially from Orani in Bataan to the coastal towns of Pampanga. Sandflat areas associated with mudflat areas are also used for shellfish culture. The approximate area of mudflat/ sandflat, where culture farms can be found, is about 6,000 ha and extends from Bataan to Cavite.

Earlier reports show that there were more species of gastropod and bivalve mollusks in Manila Bay than just oysters and mussels. Seale (1912) listed figures of 28 food species. Talavera and Faustino (1983) reported 45 species, mostly bivalves. Subsequently, Gabral-Llana and Cabrera (1985-1987) reported 43 species, mostly venerid and ark shell species. One important finding of the latter study was the absence of windowpane oyster. The windowpane oyster used to be gathered and actually cultured in the eastern areas (Metro Manila) of Manila Bay. 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 over-exploitation 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 could gather from 5,000 to 10,000 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, certain heavy metals and pesticides in shellfish tissue.

**Table 7. Retrospective Analysis for Shellfisheries in Manila Bay.**

| Resource Type | Areal Extent | Results | | Impact |
|---|---|---|---|---|
| | | Change/s Observed | Identified Agent/s | |
| Shell fisheries | Small | Quantity:<br>• Oyster: unstable prod. from 6,600 mt in 1982, 892 mt in 1992 to 5,143 mt in 1999<br>• Mussel: unstable prod. 3,105 mt in 1982, 10,827 mt in 1993 to 5,143 in 1999<br>• Disappearing windowpane oyster (from 450 to 460 seedlings/m $^2$ in Parañaque in 1947)<br>• Reduced shellfish species diversity (from 43-45 species to lesser value)<br><br>Quality:<br>• Contamination of shellfish tissue with coliform, heavy metals and pesticides | Most Likely:<br>• Overharvesting/ overcollection<br><br>Possibly:<br>• Pollution: Dumping of domestic and industrial sewage/ heavy metals, TSS, pesticides, PAH, oil and grease<br>• Destruction of habitats (through reclamation/ conversion and destructive fishing methods<br>• Plankton blooms (causing anoxic conditions) | • Loss of economically important species<br>• Reduced yield (production) |

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

The retrospective analysis for shellfisheries in Manila Bay is summarized in Table 7.

### 3.3.2.2. Attributed Causes of the Decline

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 sharp decline in oyster and mollusk production in 1988 coincided with the first red tide episode in the bay and in subsequent years (1988 - 1992) which were also marked with several red tide occurrences. 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.

Fishpond development is also starting to encroach upon the mangrove areas and mudflat/ sandflat areas where wild and cultured shellfish species thrive.

As of 1995, fishpond areas from Orion, Bataan looping to the Navotas area cover approximately 30,000 ha. This development contributed to the decimation of mangrove areas in the entire bay from about 2000 ha in the early 1990s to roughly 800 ha at present.

Loss of habitat (mangrove and mudflat areas) is a likely contributor to the decline of shellfishery in Manila Bay. The causal relationship between decline in shellfish production and loss of habitat has also been observed by fisherfolks, especially in the Bataan coast where fishpond development is slowly increasing (based on interviews and perceptions of Bataan fisherfolks, BIGKIS-Bataan PMD inspection, 2000).

Another contaminant that is known to affect adversely 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. There were documented reports of cultured mussels and oysters that perished due to reduced DO levels during the height of the red tide bloom in Bacoor Bay in 1987.

Retrospective economic analysis of productivity and revenue of shellfisheries (i.e. oyster and mussel) in Manila Bay for the recent period of 1990 to 1997 are presented in Table 8. The revenues peaked in 1992-1993 but have declined sharply thereafter.

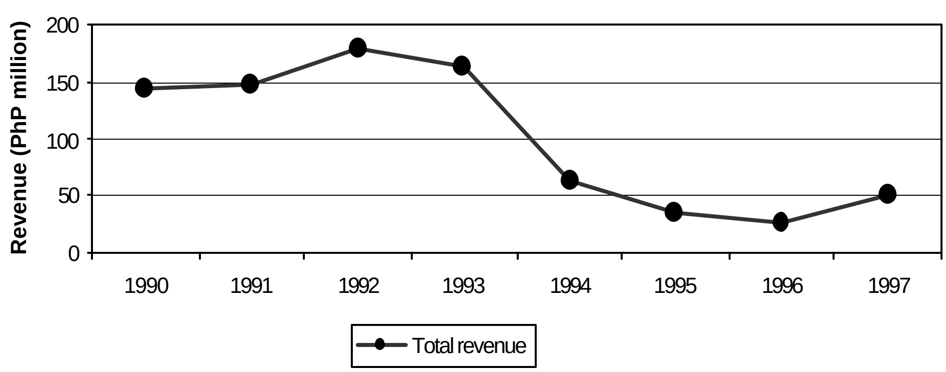
The graphical presentation of the combined shellfishery (mussel and oyster) retrospective revenue data analysis in Manila Bay from 1990-1997 is shown in Figure 8.

**Table 8. Retrospective Productivity and Revenue Data for Shellfisheries in Manila Bay.**

| Shell fish | Productivity/ Revenue | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 |
|---|---|---|---|---|---|---|---|---|---|
| Oyster & Mussel | Total Harvest | 10,440 | 10,067 | 11,549 | 16,718 | 5,050 | 3,748 | 5,614 | 8,909 |
| | Total Revenue (Php '000) | 144,947 | 147,639 | 178,665 | 162,691 | 63,078 | 35,552 | 25,917 | 50,932 |
| | Production Cost (Php '000) | 49,926 | 50,852 | 61,540 | 56,038 | 21,726 | 12,245 | 89,26 | 17,543 |
| | Net Income/ Benefit (Php '000) | 95,020 | 96,785 | 117,124 | 106,652 | 41,351 | 23,306 | 16,990 | 33,388 |

*Source: National Statistics Coordination Board, 1999.*

**Figure 8. Retrospective revenue data for shellfisheries in Manila Bay.**




*Source: National Statistics Coordination Board, 1999.*

### 3.3.3. Seaweed

#### 3.3.3.1. Evidence for Changes in Seaweed

With the lack of available comparative historical information, it was not possible to determine a decline in seaweed in the bay. Based on the Resource and Ecological Assessment of Manila Bay (BFAR, 1995), the available information only pertains to recent distribution which is widespread, with 52 species found belonging to 33 genera, 21 families, and 15 orders. Rhodophyta, Phaeophyta, and Cholorophyta are 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 9.

From eight sampling stations within the bay, it was established in 1993 that seaweed 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. Intermediate mean abundance (35 to 47 ind/0.5 $m^2$) was observed 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.

**Table 9. Retrospective Analysis for Seaweed in Manila Bay.**

| Resource Type | Areal Extent | Results: Observations | Results: Potential Agent/s | Potential Impact of Decline |
|---|---|---|---|---|
| Seaweeds | Small | Information provided in available literature:<br>• 52 species<br>• most common orders:<br>o Rhodophyta, Phaeophyta, and Chlorophyta<br>o *Sargassum* and *Gracilaria* as dominant species<br>**As of 1996**<br>Available information:<br>• 28 seaweed species available dominated by :<br>• *Sargassum spp* in Alas asin, Mariveles, Bataan and Corregidor<br>• Chaetomorpa in Freedom Island in Parañaque<br>**Other species include:**<br>1 *Gracilaria verrucosa*<br>2 *Tolyprocladia glomerulata*<br>3 *Caulerpa racemosa*<br>4 *Enteromorpha clathrata*<br><br>Cumulative Frequency value:<br>40.89-93.08 / 21.58 percent<br><br>Cumulative Cover Value:<br>• 35.79-75.20 / 15.46 percent | • Sedimentation<br>• Utilization<br>• Bottom-dragged nets<br>• Pollution:<br>Oil and Grease<br>Oil Spills<br>Heavy Metals<br>Pesticides<br>PAH<br>• Proliferation of *baklad* | • Loss of economically important species<br>• Loss of ecological functions<br><br>- Food for marine animals<br><br>- Source of nutrients |

*Source: BFAR, 1995 and Bonga et.al, 1996.*

### 3.3.3.2. Potential Agents for Decline in Seaweed

Potential agents known to adversely affect seaweed include sedimentation, utilization, bottom-dragged nets, and pollution. Sedimentation is particularly a concern in the north and northeastern sections of the Bay where industrial and urban development are greater (BFAR, 1995). A related study made by San Luis *et al.* (1995) in Pagbilao Bay indicated a decrease in seaweed due to over-harvesting and grazing by sea urchins.

### 3.3.3.3. Consequences of Decline in Seaweed

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

Marine benthic algae or seaweed is an important marine resource since practically all organisms living in the water are dependent upon algae for food. They also provide an important habitat for many marine organisms. Several seaweed genera are highly valued as food while others are sources of gels and chemicals used commercially in the manufacture of several products. Like seagrass, seaweeds are valuable economically and ecologically and serve as shelter for resident and transient adult and juvenile animals like the endangered sea turtles and animals like dugong; as food for grazers, epiphytes and detritus feeders; and as nursery grounds for species that spend their adult lives outside the community.

Seaweeds do not only represent a supply of food to marine animals, they also supply oxygen through their photosynthetic process although they also need oxygen in the process. Fortunately, the photosynthetic rate is much greater than respiration rate thus leaving sufficient oxygen supply for other aquatic organisms. Seaweeds may also play a role in carbon sequestration.

According to San Luis *et al.* (1995), the very low diversity and abundance of the reef-associated marine algae resources in their study area in Pagbilao Bay, Quezon may be attributed to the general conditions at these sites. Low abundance of fish associated with high abundance of sea urchins were noted in their assessment study. The authors allude the destruction of seaweed to grazing by sea urchins, over-harvesting, and natural destruction. They also associated the absence or low abundance of fish to the low abundance of seaweed. Some observations from this study may be useful in assessing the status of seaweeds in Manila Bay, potential causes for any decline as well as consequences of decline.

Although there is no exact report on the loss of seaweeds in the Philippines, it is estimated that five times as many fishes that depend on seaweed and other marine submerged plants, will be deprived of this ecologically important marine resources (SEAFDEC, 2001).

## 3.3.4. Phytoplankton

### 3.3.4.1. Evidence for Changes in Phytoplankton

There are no available data that 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) identified 63 genera of six algal divisions in the sampling stations occupied. *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 10 summarizes the findings of the retrospective analysis for phytoplankton.

It is estimated that nearly 80 percent of the oxygen of the world is produced by the phytoplankton through the process of photosynthesis. They make use of $CO_2$ and water as raw materials to produce their own food and release oxygen in the marine environment.

$CO_2$ is the result of respiration from marine plants and animals and from the decomposition of their organic component. These raw materials are used to produce simple sugars through photochemical reaction and can be converted into complex substances and stored as food reserves for future use. The simplified version of the role of the phytoplanktons is that it is a complex system of delicately balanced interrelated factors (Smith,1977).

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 period of observation (1996-1998). In terms of abundance, phytoplankton does not appear to be at risk but in terms of species composition, there may have been shifts over time.

Chlorophyll pigments which are the basic biological components involved in the photosynthesis in plants and algae are widely accepted as a component in measuring biomass and the physiological condition of the algae. It is also a useful indicator of water quality when the ratio of algal biomass to chlorophyll-a is taken (autotrophic index).

Martinez-Goss (1999) reported that chlorophyll-a values of Laguna Lake range broadly from 3.164 to 47.363 ng/L. The records indicate that the lake is highly entrophic. Martinez-Goss also concluded that chlorophyll analysis is closely related to the biovolume of the phytoplanktons.

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 on it in the food chain.

**Table 10. Retrospective Analysis for Phytoplankton in Manila Bay.**

| Resource Type | Areal Extent | Results | | |
|---|---|---|---|---|
| | | Observations | Potential Agents | Potential Impact |
| Phytoplankton | Large | Information from available relevant literature:<br>• genera present – 63<br>• dominant group: Baccilariophyta (among stations)<br>• period of highest diversity and density is Jan-Mar 1993, while<br>• period of lowest diversity and density is April 1993) | Possible agent for decline:<br>• Total suspended solid (TSS)<br><br>Possible agent for increase:<br>• Nutrients | • Decline:Loss of ecological functions (they are basic components in the marine environment) and carbon sequestration<br><br>Increase:<br>• Occurrence of harmful algal blooms |

*Sources: BFAR, 1995.*

## 3.4. HABITATS

### 3.4.1. Mangroves

#### 3.4.1.1. Evidence of Decline in Mangroves

Most of the data utilized for the assessment of mangroves was taken from the Resource and Ecological Assessment of Manila Bay (BFAR, 1995). It was estimated that there were around 54,000 ha 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 ha left, which were further reduced to 794 ha 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. In 1996, a Resource and Ecological Assessment conducted in Manila Bay (Bonga *et al.*, 1996) reported a total of seven mangrove species belonging to five families. These are: *Rhizophora mucronata, Nypa fruticans, Sonneratia alba, Avicennia marina, Avicennia officinalis, and Aegiceras corniculatum. R. mucronata* and *N. fruticans* are the most common species. In terms of relative density, relative frequency and relative dominance values, *R. mucronata* dominates the stands of Manila Bay.

In terms of community structure, the areas of Camachile, Orion, Bataan; Tabing-ilog, Samal, Bataan; and Matilakin, Malolos, Bulacan are probably the largest contiguous mangrove stands still existing in the bay today. The mangroves fringe the coast from about 80-200 meters (m) as buffers around fishponds and salt beds. In other areas in Cavite, Bataan and Bulacan, a 10-40 meter buffer also exists.

This is in stark contrast to the status of mangroves in the 1920s up to the 1960s when private mangrove cultivation around Manila Bay was extensive (Cabahug et al., 1986) extending up to more than 20 km inland from the bay to supply the Manila market with firewood and housing materials.

The retrospective analysis of mangroves in Manila Bay is shown in Table 11.

#### 3.4.1.2. Attributed Causes of the Decline in Mangroves

The major cause of the decline in mangroves 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 possible factors that could have contributed to 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 at 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.

#### 3.4.1.3. Consequences of Decline in Mangroves

Destruction of mangrove forests in Manila Bay have led to a 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

**Table 11. Retrospective Analysis for Mangroves in Manila Bay.**

| Habitat Type | Areal Extent | Results | | Impact |
|---|---|---|---|---|
| | | Change/s Observed | Identified Agent/s | |
| Mangroves | Small | **Quantity:**<br>Very large decline – baywide from an estimated 54,000 ha in 1890 to 2,000 ha in 1990; and from 2,000 ha in 1990 to 794.37 ha in 1995<br>- private mangrove cultivation extensive in 1920-1960 (Malabon to Bataan)<br><br>**Quality:**<br>No base data to describe quality change<br><br>**As of 1996**<br>Species composition and abundance:<br>Seven major mangrove species identified:<br>*Rhizophora mucronata*<br>*Nypa fruticans*<br>*Sonneratia alba*<br>*Avicennia marina*<br>*Avicennia officialis*<br>*Aegiceras corniculatum*<br><br>Relative density, frequency and dominance data available<br><br>Average basal areas: 18.08m²/ha | Likely:<br>• Physical removal for the ff. activities:<br>•Conversion (i.e. for aquaculture and salt beds)<br>•Land reclamation and other development activities<br>•Cutting for fuelwood and housing<br><br>Possibly:<br>• Pollution: oil spills, pesticides<br>• Sedimentation from upland activities<br>• Pest infestation (localized)<br>• Lahar suffocation (localized) | • Degradation or loss of habitat and nursery grounds<br>• Loss of natural protection<br>• Reduced biodiversity<br>• Coastal erosion and siltation<br>• Loss of carbon storage<br>• Reduced nutrient detritus<br>• Secondary adverse impacts to adjacent coral reefs, sea grass beds, and other habitats<br>• Reduced energy subsidy |

*Source: BFAR, 1995, Cabahug et al., 1986, and Bonga et al., 1996.*

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.

### 3.4.2. Coral reefs

#### 3.4.2.1. Evidence for Decline in Coral Reefs

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 Manila Bay from 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. has 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 percent in Mariveles, 40 to 80 percent in Cavite (Limbones Cove), and 20 percent in Corregidor Island. There were about 14 families of hard corals and one family of soft corals comprising 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 12.

The 1996 report (Bonga et al., 1996) showed that percentage of live coral cover (both hard and soft) ranged from 10.9 percent to 70.9 percent. Living hard corals were mainly dominated by

**Table 12. Retrospective Analysis for Coral Reefs in Manila Bay.**

| Habitat Type | Areal Extent | Results | | Impact |
|---|---|---|---|---|
| | | Change/s Observed | Identified Agent/s | |
| Coral Reefs | Small | **Quantity:**<br>There was decline but no actual/ estimated figures available/ ecological status categorized as poor<br><br>**As of 1992 – 1993:**<br>• percent live cover: 20 in Mariveles, 40 to 80 in Cavite (Limbones Cove), and 20 in Corregidor Island<br>• 14 families of hard corals, one family for soft corals composed of 38 genera and 53 species<br><br>**Quality:**<br>Information from available relevant literature/studies:<br>• structure: fringing type composed of generally encrusting and massive in habit / no solid stands / dispersed and occurring in patches / most colonies young and small<br><br>**As of 1996:**<br>Percent live coral cover<br>Calumpang (Cavite) – 69.4 percent<br>Marbella - 36..3 percent<br>Alas-asin - 37.3 percent<br>Corregidor – 25.1 percent<br>Lucanin – 10.85 percent<br>Dead Coral Cover:<br>Alas asin – 0.4 percent<br>Calumpang – 12.2 percent<br>Algal Cover:<br>Calumpang - ..3 percent<br>Corregidor – 7.2 percent<br>Sponges – found only in Corregidor<br>Abiotic component (sand)<br>Calumpang – 10.2-84.9 percent<br>Lucanin – 84.9 percent<br>Reef Fish Communities:<br>Species abundance/ composition<br>• *Dascyllus reticulatus* – 20.\06 percent<br>• *Chromis ternatensis* – 9.72 percent<br>• *Pomacentrus grammorhynchus* – 9.26 percent<br>• *Chromis viridis* – 6.14 percent<br>• *Pomachromis richardsoni* – 5.37 percent<br>Biomass:<br>1 *C. ternatensis* – 19.88 percent<br>2 *Thallasoma lunare* – 15.18 percent<br>3 *Gymnothorax* sp – 5.49 percent<br>4 *Cephalopholis boenack* – 4.29 percent<br>5 *P. richardsoni* – 4.28 percent<br><br>Annual fish production for the reef system 2.38± 1.39 $mt/km^2/yr$. | • Physical destruction (i.e., dynamite fishing)<br>• Cyanide/<br>• poison fishing in the reef area<br>• Siltation<br>• Gathering<br>• Fishing gears and attachments (trawls and motorized pushnets)Incr eased boat anchorage | • Degradation or loss of habitat<br>• Reduced fishery production<br>• Reduced tourism potential<br>• Reduced physical protection<br>• Reduced biodiversity<br>• Loss of carbon sequestration |

*Source: BFAR, 1995; Bonga et al., 1996.*

massive and encrusting non-*Acropora* species. Calumpang, a marine reserve in Cavite, gave the highest live coral cover with an average of 69.4 percent or good condition. Marbella, Alas-asin and Corregidor are in relatively fair coral condition with an average live coral cover of 36.3 percent, 37.3 percent and 25.1 percent, respectively. Reef condition in Lucanin is relatively in poor condition with 10.85 percent.

The results of this study when compared with the results of the REA in 1992-1993 (BFAR, 1995) indicate that reef condition at Calumpang, Corregidor and Lucanin are generally in the same category. The live coral cover at these stations was 82.5 percent (average for Calumpang I and II), 26.3 percent (Corregidor II) and 18.4 percent (Lucanin). The differences of percentage cover of this study with the REA results may be due to variation in the location and depth of transect stations.

In terms of dead corals, percentage cover ranged from 0.4 percent (Alas-asin) to 12.2 percent (Calumpang). Algal cover ranged from 0.3 percent (Calumpang) to 7.2 percent (Corregidor). Abiotic component of the benthos ranged from 10.2 percent (Calumpang) to 84.9 percent (Lucanin) and dominated mainly by sand category. At the transect station in Corregidor, there is a relatively high percentage of sponges.

The health of coral reef can be measured by the amount and quality of corals that are present (both hard and soft) and species richness of the organisms that depend on it (Meñez *et al.* 1991). The present status of the coral reef resources of Manila Bay is generally classified as in poor to good condition. Based on the transect sampling results of the five study areas, the average cover of living corals (both hard and soft) in Manila Bay was estimated to be 40 percent or fair condition.

The top five coral reef fish species with the highest individual abundance were *Dascyllus reticulatus* with total individuals of 392 or 20.06 percent out of the 1,954 total fish for all sites during the two samplings. This was followed by *Chromis fernatensis* (190 or 9.72 percent), *Pomacentrus grammorhynhus* (181 or 9.26 percent), *Chromis viridis* (120 or 6.14 percent), and *Pomachromis richardsoni* (105 or 5.37 percent).

In terms of fish biomass, out of the computed total of 8,495.29 grams, *C. ternatensis* topped the list with 1,689 grams (19.88 percent), followed by *Thallasoma lunare* (1,290 grams or 15.18 percent), *Gymnothorax sp* (467 grams or 5.495), *Cephalopholis boenack* (365 grams or 4.29 percent) and *P. richardsoni* (364 grams or 4.28 percent).

Based on the estimated biomass of 1.59 + 0.93mt. $km^{-2}$ and the production to biomass (P/B) ratio of 1.5 (Polovina 1984), the computed annual fish production for the reef systems is 2.38 + 1.39 mt. $km^{-2}$ $yr^{-1}$.

#### 3.4.2.2. Attributed Causes of Reduction in Coral Reefs

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.

#### 3.4.2.3. Consequences of Reduction in Coral Reefs

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

### 3.4.3. Seagrass Beds

#### 3.4.3.1. Evidence for Decline in Seagrass Beds

Available data (BFAR, 1995 and Bonga et al., 1996) only include information on species, abundance, and diversity. In the 1995 report, *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 has 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 (BFAR, 1995).

The 1996 report (Bonga et al., 1996) recorded six species only in Patungan, Maragondon, Cavite dominated by *Cymodocea rotundata.* The highest

**Table 13. Retrospective Analysis for Seagrass in Manila Bay.**

| Habitat Type | Areal Extent | Findings: Observations | Findings: Possible Agent/s | Potential Impact of Decline |
|---|---|---|---|---|
| Seagrass | Small | Available Information:<br>Only five species –<br>• Dominated by two (2) species *Halophila ovalis* and *Halodule pinofolia*<br>• Abundance (ind/0.5m$^2$):<br>Orion, Bataan – intermediate (12)<br>Mariveles, Bataan – low (5 and 6)<br>Limbones – high (23)<br>Corregidor Island – low (5 and 6)<br>• Diversity Index:<br>Orion, Bataan – high (0.59 – 0.69)<br>Mariveles, Bataan – low (0)<br>Limbones – high (0.59 – 0.69)<br>Corregidor Island – high (0.59-0.69)<br>Over-all – low diversity<br><br>**As of 1996:**<br>• Six species recorded only in Patungan, Maragondon, Cavite dominated by *Cymodocea rotundata*<br>• Diversity index:<br>Patungan, Maragondon, Cavite – (high) 1.45<br>Corregidor – 1.40<br>Alas-asin –1.24<br>Freedom Island (Parañaque) – (low) 0.57<br>• Dominance Index:<br>Freedom Island (high) 25.87<br>Patungan 7.22<br>Corregidor 5.22<br>Alas-asin (low) 4.95<br>Biomass value :<br>22.0 – 61.4g.dw/m$^2$<br>Cumulative frequency and cover value :low | Likely:<br>• Sedimentation<br>• Conversion of coastal areas for open water fish culture<br>• Trawling<br><br>Possibly:<br>• Dynamite fishing and other destructive fishing methods<br>• Discharge of domestic and sewage or industrial wastes<br>• Oil and Grease<br>• Oil Spills<br><br>Unlikely:<br>• Heavy metals<br>• Pesticides<br>• PAHs | • Loss of economically important species<br>• Loss of shoreline protection (stabilizes the action of waves)<br>• Lost of habitat and nursery grounds<br>• Reduced detritus |

*Source: BFAR,1995 and Bonga et al., 1996.*

diversity index (1.45) was obtained in Patungan, Maragondon, Cavite while the lowest diversity index (0.57) was obtained in Freedom Island in Parañaque. The dominance index was highest at Freedom Island (25.87) and lowest at Alas-asin, Mariveles, Bataan (4.95). Reported biomass value was 22.0 - 61.4 gram dry weight (g.dw)/$m^2$. Cumulative frequency and cover value was determined as low.

The common areas covered by the two studies were Corregidor Island and Mariveles, Bataan. Higher diversity indices were reported in the 1996 study although the dominant species reported were different. It was, therefore, difficult to perform a comparison of the results of the two studies since the specific survey stations covered may have been different.

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 13.

#### 3.4.3.2. Potential Causes of Reduction in Seagrass Beds

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 and incidence of oil spills. Based on conditions within and around the bay, the likelihood that these agents may cause decline in seagrass beds is presented in Table 13.

#### 3.4.3.3. Consequences of Reduction in Seagrass Beds

Decline in seagrass beds 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.

### 3.4.4. Soft Bottoms, Mudflats, Sandflats, Beaches and Rocky Shores

#### 3.4.4.1. 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 variability in 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 clay. 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.

**Table 14. Retrospective Analysis for Soft-bottoms, Mudflats, Sandflats, Beaches and Rocky Shores in Manila Bay.**

| Habitat Type | Areal Extent | Findings | | Impact |
|---|---|---|---|---|
| | | Observations | Agent/s | |
| Soft Bottoms | Large | 1992-1993 (BFAR, 1995):<br>Signficant differences in mean population density between stations<br>- Corregidor-highest density<br>- Navotas-lowest density<br>Different dominant communities between stations<br><br>1996-1998 (PRRP, 1999):<br>Quantity:<br>- 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.<br>- 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.<br><br>Quality:<br>Community structure - dominated by polychaetes/ low species diversity | Most likely:<br>• Low DO<br>• Sedimentation (reclamation activities)<br>• Physical Disturbance (fishing activity)<br><br>Possibly:<br>• Pollution:<br>Oil and Grease<br>Heavy Metals<br>Pesticides<br>Other organics<br>PAH<br>TSS | • Degradation or loss of habitat<br>• Loss of benthic organisms, reduced diversity<br>• Decline in fish production<br>• Loss of function in regulation of organic loading |
| Mudflats | Moderate | Total Area: 4,600 ha<br>Bulacan: 2,457 ha<br>Pampanga: 1,340 ha<br>Bataan: 803 ha | Likely:<br>• Reclamation<br>• Conversion | Degradation and/or loss of habitat |
| Sand flats | Small | Total Area: 1,500 ha<br>Bataan: 723 ha<br>Cavite: 537 ha<br>Metro Manila: 240 ha | Likely:<br>• Reclamation<br>• Conversion<br>• Pollution | Degradation and/or loss of habitat |
| Beaches | Small | Total Area: no data<br>Location: Ternate Cavite, southern part of Metropolitan Manila, and Cochinos Point, Mariveles Bataan<br>Composite floral cover: herbs (61.20%), trees (21.50%), shrubs (9.50%), and vines (7.80%) | Likely:<br>• Reclamation<br>• Conversion<br>• Physical Destruction | Degradation and/or loss of habitat |
| Rocky shores | Small | No data on exact location and condition | Likely:<br>• Reclamation<br>• Conversion<br>• Physical Destruction | Degradation and/or loss of habitat |

*Sources: BFAR, 1995 and PRRP, 1999.*

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 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/$m^2$). It was also noted that benthos annelids were mostly polychaetes larvae and that the presence of Capitellidae and Spionidae (annelids) is an indication of habitats under stress due to high organic pollution and sulfidic conditions (PRRP, 1999).

There was also a noted shift, in terms of community structure, from a bivalve-dominated community to an increasingly polychaete-dominated community. Table 14 details the retrospective analysis for soft-bottoms in Manila Bay.

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 of the mudflats are found in Bulacan, 29 percent in Pampanga, and 17 percent in Bataan. Based on the same study, total sand flat area is 1,500 ha, and this composite is distributed in Bataan (47 percent), Cavite (36 percent), and Metro Manila (16 percent), 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 Cochinos Point in Mariveles, Bataan. In addition, these areas were found to have composite floral cover of herbs (61.20 percent), trees (21.50 percent), shrubs (9.50 percent), and vines (7.80 percent).

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. Rocky shores are considered as least important - and therefore least studied - compared with other habitats or resources found within the bay.

Estimates of loss or degradation of mudflats, sand flats, beaches, and rocky shores cannot be obtained due to lack of historical information. Table 14 provides the findings of the retrospective analysis for each of the aforementioned habitats.

#### 3.4.4.2. Attributed Causes of Decline

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 BOD and 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.

**Table 15. Retrospective Analysis for Shoreline Movement in Manila Bay.**

| Resource Type | Areal Extent | Results | | Impact |
|---|---|---|---|---|
| | | Change/s Observed | Identified Agent/s | |
| Shoreline Changes | Large | Quantity ($m^2$)<br><br>From 1944-1961 Maps:<br>• Bataan - ~ 387.5 $m^2$ net land gain<br>• Pampanga - ~ 57.7 $m^2$ net land loss (note: some segments have no 1944 data, see Figure 10)<br>• Bulacan - no 1944 data<br>• Manila - ~70.3 $m^2$ net land loss<br>• Cavite - ~ 98.7 $m^2$ net land loss<br><br>From 1961-1977 Maps:<br>• Bataan - ~179.1 $m^2$ net land gain<br>• Pampanga - ~ 415.8 $m^2$ net land gain<br>• Bulacan - ~5,280.9 $m^2$ net land loss<br>• Manila - ~ 6,147.7 $m^2$ net land gain<br>• Cavite - no 1977 coastline data<br><br>From 1977-1991 Maps:<br>• Bataan - ~1,042.6 $m^2$ net land gain<br>• Pampanga - ~ 1831.3 $m^2$ net land loss<br>• Bulacan - ~5,992 $m^2$ net land gain<br>• Manila - 1977 coastline data the same as 1991<br>• Cavite - no 1977 coastline data<br><br>From 1944-1991 Maps<br>• Bataan - ~ 2,197.2 $m^2$ net land gain<br>• Pampanga - ~ 507.5 $m^2$ net land gain<br>• Manila - ~6,077.4 $m^2$ net land gain<br>• Cavite - ~78.1 $m^2$ net land gain<br><br>From 1961-1991<br>• Bulacan - ~ 711.1 $m^2$ net land gain | Likely causes of erosion:<br>• Global and local sea level rise<br>• Decrease of sediment input from inland due to dam and other river works (e.g. Pampanga, Angat and Pasig rivers)<br><br>Possible causes of progradation:<br>• Increased sediment input due to river works for flood mitigation project and deforestation<br>• Man-made activities (reclamation projects) | • Damage to property<br>• Destruction/loss of natural habitat |

*Sources: Siringan et al., 1997 and Siringan and Ringor, 1998.*

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.

Sedimentation which directly resulted in bottom topography and bathymetric changes of the bay, may have contributed to the destruction of benthic community.

Reclamation activities and continuous conversion, and in some cases, pollution, may contribute to the degradation or loss of mudflats, sandflats, beaches, and rocky shores.

Moreover, shoreline changes which are evident along the bay may influence the change of structure, and ecology of mudflats, sandflats, beaches and rocky shores.

#### 3.4.4.3. Consequences of Decline

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. In contrast, there was low benthos density and low fish catch in areas near discharge or outfalls of sewers and in pollution sinks, which have observed high concentrations of heavy metals and other debris.

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.

## 3.5. PHYSICAL CHANGES AND THEIR EFFECTS ON RESOURCES AND HABITATS

### 3.5.1. Shoreline Changes

Time series analysis of maps and remotely sensed images by Siringan and others (1997) and Siringan and Ringor (1997; 1998) show the changes in the position of the shoreline along the coast of Manila Bay during the past few to several tens of years ago. These works show that different coastal segments exhibit different histories of shoreline migration. Described below are the changes of shoreline positions along the different segments of Manila Bay (Figure 9) based on the results of the above-cited works. The values in Table 15 may be misleading in the sense that it may give an impression that there is minimal change. The calculations are based on general trends and should be taken together with the maps showing the changes in shoreline position (Figure 10).

***Bataan Coastline***

From 1944 to 1991, almost the entire length of the shoreline underwent progradation which is evident between the coast of Limay and north of Talisay River. Progradation also occurred in areas adjacent to Mamala-Duate River. Changes in these areas register approximately 250-300 m of progradation. The net shoreline change is advancement of approximately 2197.2 $m^2$.

***Pampanga Coastline***

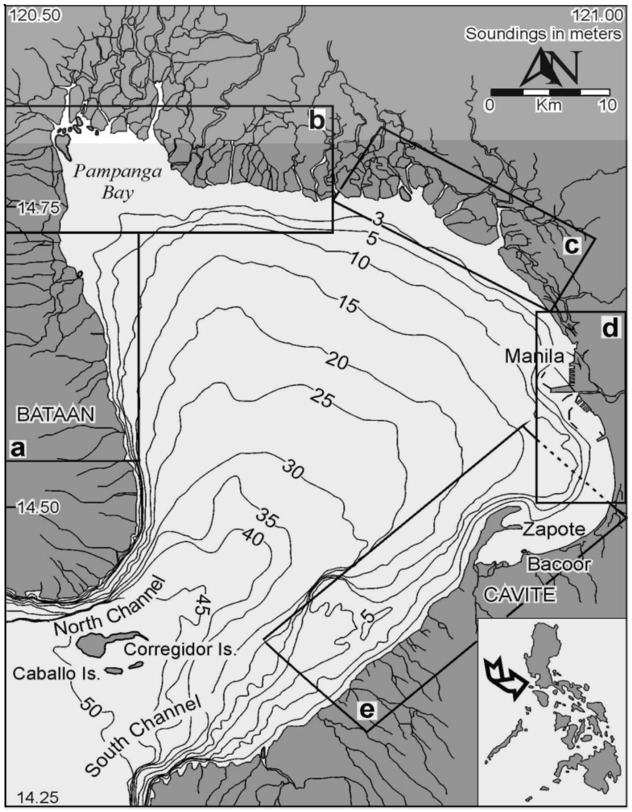
From 1944-1991, progradation of as much as 200 m is evident south of Kalaguiman River. In contrast, no systematic migration of shoreline position occurred between the coasts of Orani and Hagonoy. However, the irregular shoreline configuration in 1944 which is a characteristic of undisturbed coast changed to a more linear configuration in 1977 and 1991. The linearity of the coast is attributed to land use of the area, in particular, as fishponds. Hence, short-term changes in shoreline position in this segment are most likely man-induced. Old maps and anecdotal accounts indicate that this area used to be covered with mangroves prior to its conversion to fishponds. Approximately 507.5 $m^2$ of land was gained from 1944-1991.

***Bulacan Coastline***

From 1961 to 1977, between Capiz and Meycauayan rivers, an extensive area of the shoreline retreated. However, from 1977 to 1991, the change is predominantly progradation showing a linear coastline which indicates man-made structures such as fishpens. This segment of the coast along Manila Bay shows the largest change

**Figure 9. Index Map of the Different Coastal Segments of Manila Bay.**

*Note: Boxed areas indicate the location of the different coastal segments enlarged in Figure 10.*




in shoreline of the bay where as much as 1,200 m of progradation was measured. The dominant change in the shoreline position in this area from 1961-1991 is seaward with an approximate area of 711.1 $m^2$.

### *Manila Coastline*

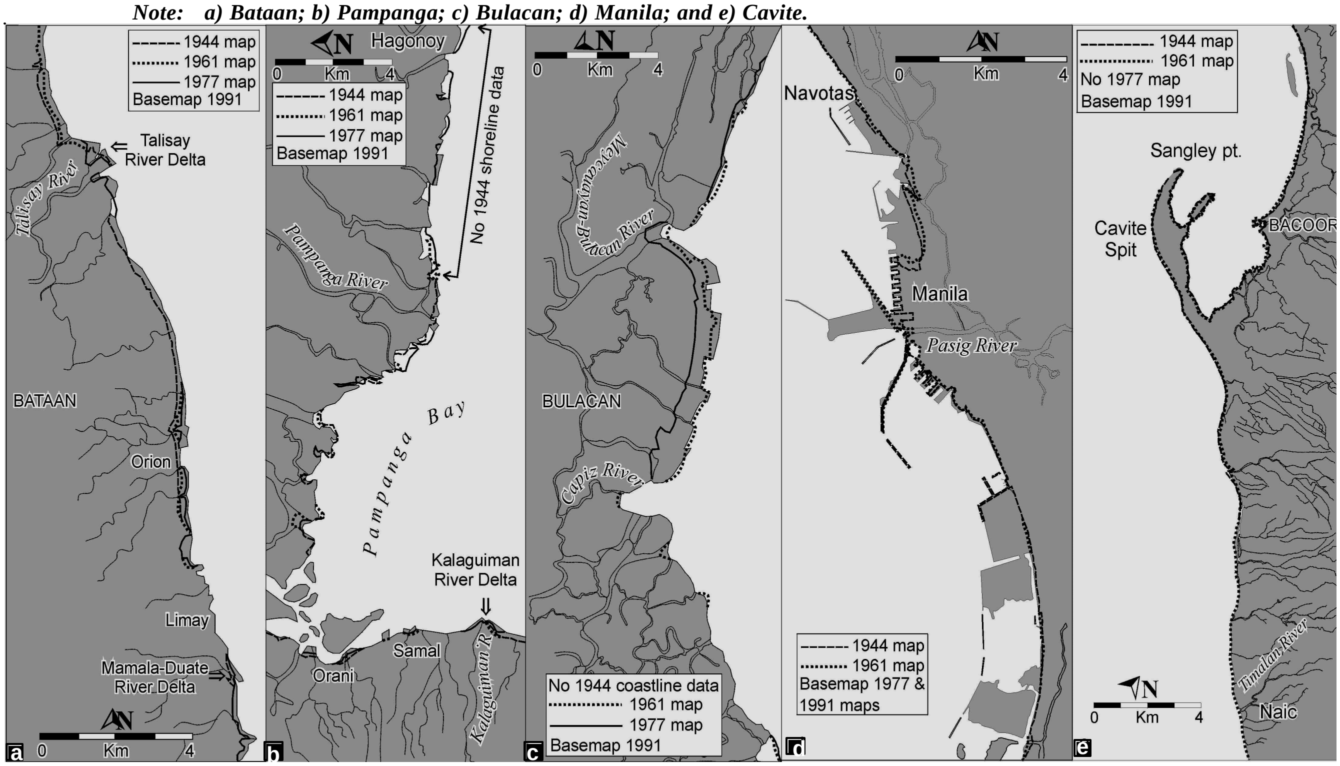
Southeast of Meycauayan River down to the vicinity of Navotas, there is minimal shoreline change. Along the coast of Metro Manila, the observed shoreline changes are due mainly to land reclamation. As much as 600 m. has been reclaimed off Tondo, immediately north of the North Harbor. Coastal retreat is documented in only a few places. Likewise, erosion has been artificially limited by the numerous seawalls and breakers in the area. Approximately 6,077.4 $m^2$ of land was reclaimed from 1944-1991.

### *Cavite Coastline*

On-site investigation and time series analysis of maps show that the southeastern part of Manila

**Figure 10. Changes in the Shoreline Position Along the Different Coastal Segments of Manila Bay.**

*Note: a) Bataan; b) Pampanga; c) Bulacan; d) Manila; and e) Cavite.*



Bay, particularly from Timalan River to the Cavite spit, experienced shoreline erosion ranging from 50-100 m. Old infrastructures such as railways which were documented in the 1944 map are no longer seen in the field. According to the anecdotal accounts of local residents, these infrastructures are approximately 50 m offshore from the present shoreline. Other than this, exposed roots of coconut trees onshore, as well as other remnants of former vegetation lining the old coast indicate an erosional coastal system. In response to the problem of erosion, local residents have put up seawalls and breakwaters.

Along the northwest-facing coastlines behind the spit, mostly natural progradation seems to have occurred. Man-induced progradation of as much as 100 m is seen between Cañacao and Sangley Point due to reclamation for the Sangley Point airstrip. The net shoreline change in the Cavite coastline is seaward. Approximately 78.1 $m^2$ of land was gained.

### 3.5.2. Attributed Causes of Shoreline Changes

Changes in the position of the shoreline along the coast of Manila are clearly man-induced as indicated by the presence of seawalls, breakers, and reclaimed areas for real estate development. East of Pampanga Bay, linearity of the coast is attributed to land use of the area, in particular, as fishponds. Hence, short-term changes in shoreline position in this segment are also most likely man-induced. Old maps and anecdotal accounts attest that this area used to be covered with mangroves prior to its conversion to fishponds. Between Capiz and Meycauayan rivers, it is uncertain whether this coastline advancement is due to natural progradation, which encouraged the presence of fishponds, or if this advancement is due to reclamation for fishpen construction. The location of this coastline updrift of Meycauayan River suggests that progradation is natural.

Reduction in sediment supply through decrease in sediment yield of Pampanga and Binangbang rivers may have caused shoreline retreat along the Pampanga coast. Pantabangan Dam, the largest multipurpose dam in the Pampanga River basin was constructed in 1971 and became operational in 1974 causing marked decrease in freshwater discharge. In addition, the Bebe-San Esteban channel was built between 1979 and 1983, redirecting the flow of Pampanga River to Pasig River (DPWH and NIA, 1988). Both would have led to reduced sediment input, thus inducing erosion.

Relative sea level rise, combination of local and global sea level rise, in the bay may have also resulted in the low retention of sediments near the coast. The Manila South Harbor tidal gauge record indicates an overall relative sea level rise of approximately 0.40 cm/yr from 1901-1950. A drastic increase in the rate of rise to approximately 2.35 cm/yr occurred between 1963 and 1980. In comparison, estimates of mean global eustatic sea level rise during the last century range from 0.12 cm/yr (Gornitz and Lebedeff, 1987) to 0.18 cm/yr (Douglas 1991). This higher rate of sea level rise, relative to the estimates of global eustatic sea level rise, is attributed to subsidence. The South Harbor is situated atop the deltaic deposits of Pasig River. Compaction of the deltaic sediments, under their own accumulating weight, may explain the relative sea level rise during period 1901 to 1950; the drastic increase in the rate of relative sea level rise during the period 1963 to 1980 could be attributed to groundwater withdrawal. The trend of groundwater withdrawal in Metro Manila (NEPC, 1987) shows an abrupt increase in the late 40's and acceleration in the early 70's. These trends correlate well with the trends of relative sea level change indicated by the South Harbor tidal gauge record.

Changes in the shoreline position along the different coastal segments of interest and indicated as boxed areas in Figure 9 are expanded in Figure 10.

The Bataan coast generally shallowed at all fathom depths which implies an increase in agricultural and aquacultural activities during the last 40 years, reinforced by surface run-offs from denuded upland areas.

The Pampanga Bay area in the northwestern portion of Manila Bay generally shallowed at all depths, especially at the one-fathom line. The Bulacan coastline indicated deepening at the one-fathom depth, but there are relatively no changes at the three-fathoms depth, shallowing at the five-fathoms depth and deepening at the 10-fathoms depth.

Along the Metro Manila coast, differential changes were noted from Navotas down to Parañaque. At the one-fathom depth, shallowing was evident; at the three-fathoms depth, appreciable deepening was noted in front of the Pasig River's mouth; at the five-fathoms isobath, continuous deepening at the mouth of Pasig River and shallowing at the Pasay portion. The shallowing of the Pasay portion could be due to depositional location where sediments borne by the longside current are lodged. There was deepening in the Parañaque portion; however, there are no relative changes after the Parañaque portion going to the Cavite coastline. The deepening trend along the Cavite coast occurred in the three- and five-fathoms isobaths.

As cited by the Final Report of the Fishery Sector Program (1995), results of actual observations during the 1993 REA study confirmed the oscillatory depth changes occurring in Manila Bay. A key factor cited by the REA report is the current system, which determines the flow and depositional patterns of sediments. The REA study postulated that the shallow coast of the northeastern section of Manila Bay is a function of three major wind-driven currents over the bay. The tremendous freshwater flow with its heavy load of sediments, especially during periods of heavy rains is also a key factor. From previous studies (J.M. Montgomerry-DCCD-Kampsax-Krugger Consultants, 1979 - cited by the FSP Final Report 1995), the current velocity induced by inflows of freshwater is in the magnitude of 0.05 m/sec except in the vicinity of rivermouths where it is greater. A considerable amount of freshwater is inputted into the bay, with volumes in the vicinity of $500m^3$/sec during the dry season and greater during periods of heavy precipitation.

Oscillatory depth changes also occur along the coast of Bulacan. Deepening at one-fathom depth of about four feet was noted while at the three- and five-fathoms depth, there was shallowing. Along the coast of Cavite, there was deepening of one or two feet in Tanza through Naic at the three-fathom depth. In Rosario and Noveleta, there was deepening at the five-fathom isobath.

Corregidor Island has deepened at its western side at the five- and ten-fathoms isobaths. Caballo Island shallowed at its southern side at the five fathoms level but deepened at ten fathoms. The depth changes at Corregidor and Caballo Islands may be considered as the natural consequence of the current system.

### 3.5.3. Changes in Currents and Wave Patterns

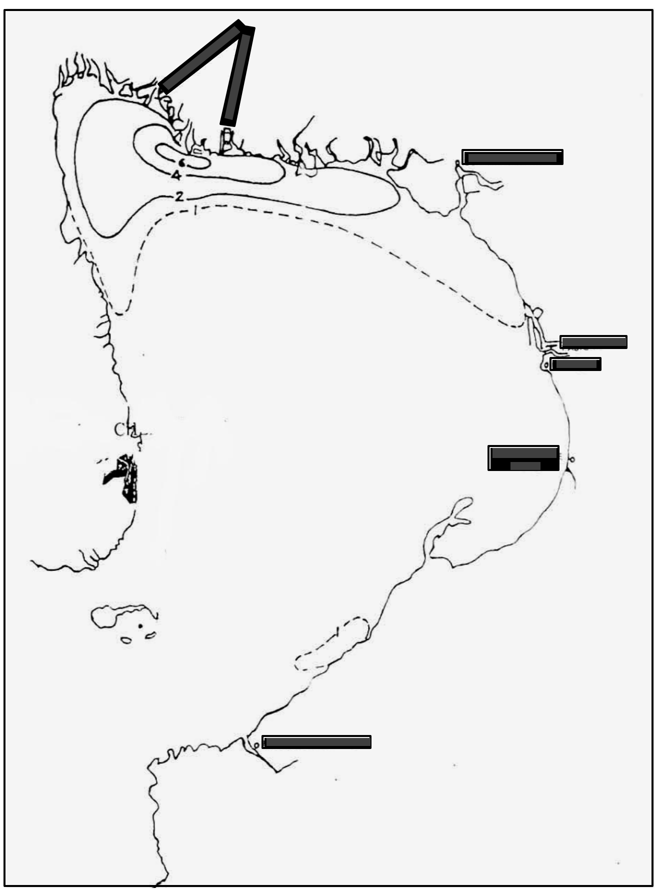
As cited from the Programmatic Environmental Impact Statement of the PNOC-PDC in 1994, Manila Bay currents is believed to be initiated by three interacting factors - winds, tides and freshwater currents. In a mathematical model developed by Delas Alas and Sodusta (1985, as cited by the PNOC-PDC EIS, 1994), wind driven currents were found to be important in the shallower parts of the bay.

Tracer studies published in 1969 and 1971 by the Danish Isotope Center and summarized in the UNEP 1991 report (from PNOC-PDC EIS 1994), also noted that tidal currents near the mouth were significant. South of Corregidor Island, the entry velocity was measured at 500 cm/sec, while at the deeper north channel, the outflow was found to be as high as 800 cm/sec. The strength of the inflow and outflow is theorized to be the main factors in the flushing of Manila Bay. As the tidal effects spread out into the bay, tidal currents fall to about five cm/sec at the shores. Water renewal in the inner part of the bay due to combined effects of winds and tides is calculated to be in the order of 1,000 $m^3$/sec on the average annually. Presented in Figures 11 and 12 are the calculated depth-average current speed for different wind directions.

Freshwater currents further complicate the flow, although these are significant only during the wet season when run-off from the rivers drain into the bay. The freshwater forms a thin layer at the surface which drives the underlying saline waters out of the bay at 5 cm/sec. Its contribution to water renewal is estimated at 1,000 $m^3$/sec during the wet season, which doubles the effect of winds and tides.

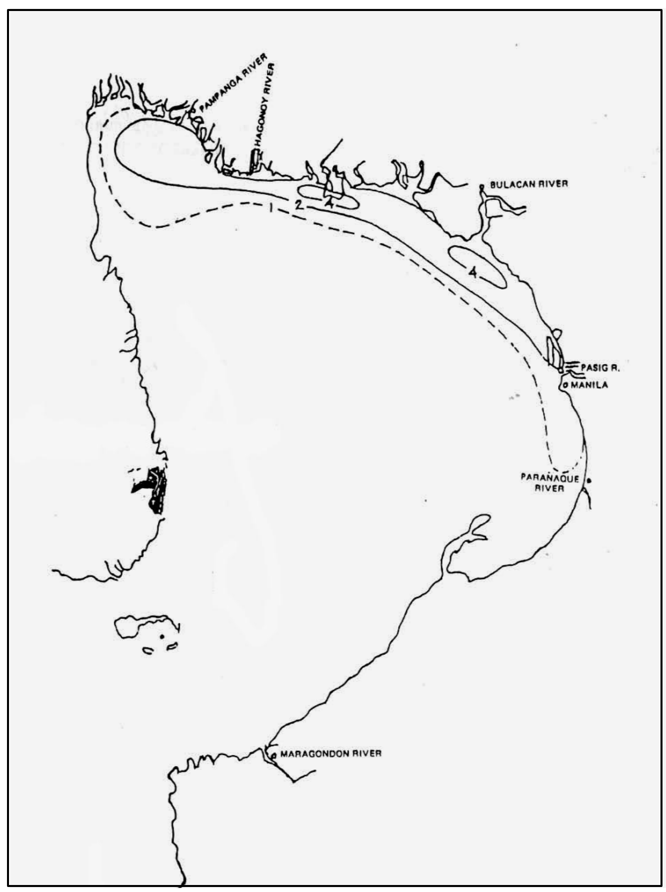
Measurements of ocean currents in Manila Bay (based on the PNOC-PDC EIS, 1994) showed that there is a preference for two opposite directions which is evident in the bay area. The flow tends

**Figure 11. Calculated Depth-averaged Current Speed in cm/sec for Northeasterly Wind Flow.**



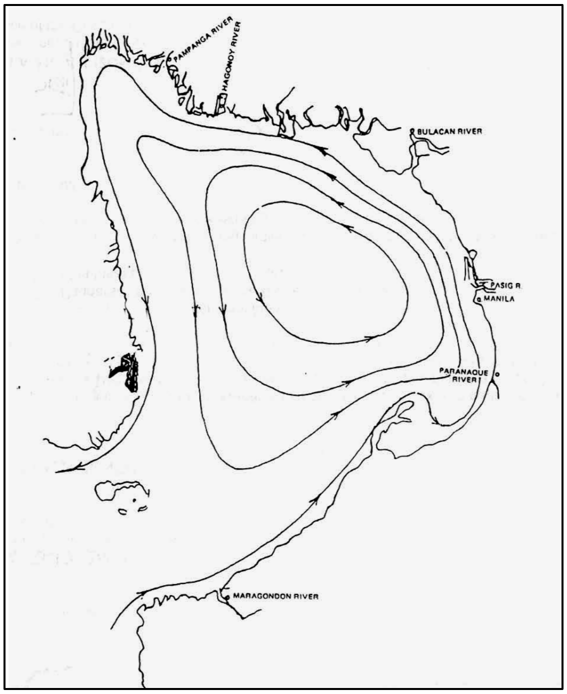
*Source: PNOC-PDC Programmatic EIS, 1994.*

**Figure 12. Calculated Depth-averaged Current Speed in cm/sec for Southeasterly Wind Flow.**




*Source: PNOC-PDC Programmatic EIS, 1994*

**Figure 13. Calculated Transport Streamlines for Southeasterly Wind Flow.**

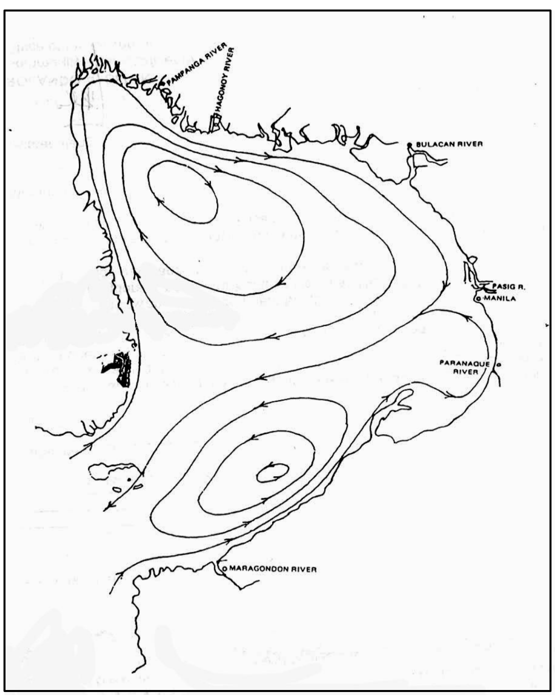



*Source: Source: De las Alas & Sodusta, 1985; PNOC-PDC Programmatic EIS*

to be more uniform and oriented along the shore, especially in the Bataan side because of its straight shoreline, hence directions of current along the Bataan coast maybe expected to follow the straight shoreline, though there will be variations in the velocity depending on wind speed and tidal amplitude. In the other parts of the bay, currents may change according to the orientation of the shoreline and as affected by wind speed and tides. Figures 13 and 14 show calculated transport streamlines for southeasterly wind while Figure 15, for northeasterly wind.

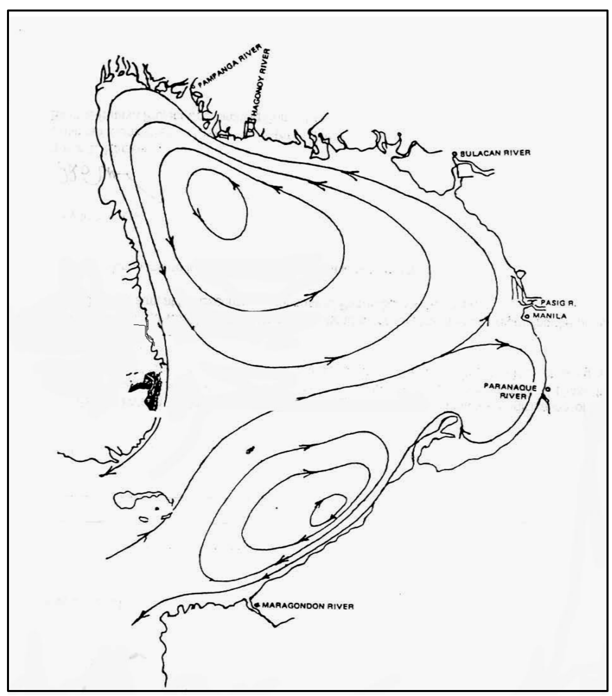
There are no records of wave measurements in the Manila Bay area. Hindcasting using speeds and likely wave heights was employed in the studies cited earlier. Calculated significant wave height may reach 1.5 m in response to maximum wind mean winds of 13 m/sec. Wave heights of 3.5 m are possibly based on observed gusts as high as 33 m/sec. These calculations apply to the Port Area; however, assuming that there are identical

**Figure 14. Calculated Transport Streamlines for Southeasterly Wind Flow.**




*Source: De las Alas & Sodusta, 1985; PNOC-PDC Programmatic EIS, 1994.*

**Figure 15. Calculated Transport Streamlines for Northeasterly Wind Flow.**




*Source: De las Alas & Sodusta, 1985; PNOC-PDC Programmatic EIS, 1994* fetches and wind durations, these calculations also apply to the other areas of the bay.

Tides in Manila Bay have been observed by the Bureau of Coast and Geodetic Surveys (BCGS) since 1948 at a station near the Manila South Harbor using an automatic recorder. Table 16 shows a summary of the tidal ranges in the bay taken from JICA, 1990 (cited from PNOC-PDC EIS 1994). Based on this record, the maximum known tidal ranges is less than 2 m and is typically less than 1.5 m. Tides impart diurnal reversal to the flow.

### 3.5.4. Bottom Topography and Bathymetric Changes

Bottom topography and bathymetric changes along with currents, waves and tides are not really resources. Rather, they are oceanographic forces that affect resources. Among the oceanographic factors mentioned, bottom topography and bathymetric changes have observable effects on the different resources around the bay.

The seaward movement of land best indicates the decline in the surface area of Manila Bay. This is caused mainly through such activities as reclamation and conversion of mangrove and mudflat areas into fishponds. Other factors include such processes as erosion and siltation. These factors have decreased the total surface area of the bay (Manila Bay Environmental Profile - Region III, 1993).

**Table 16. Tide Data in Manila Bay.**

| TIDE COMPONENT | HEIGHT (IN METERS) |
|---|---|
| Observed Highest Tide | 11.770 |
| Mean Spring Height | 11.300 |
| Mean Higher High Tide | 10.980 |
| Mean High Water | 10.838 |
| Mean Sea Level | 10.462 |
| Mean Low Water | 10.101 |
| Mean Lower Low Water | 10.000 |
| Datum Line | 0.000 |

*Source: PNOC-PDC EIS 1994.*

Based on the Coastal Resources and Land Use Map of Manila Bay which was developed by the National Museum-MADECOR team in 1993 (BFAR, 1995), fishpond areas in Manila Bay from the coastline of Orion, Bataan to the Navotas area cover an approximate 300 $km^2$ area (about 30,000 ha), most of them concentrated in the Pampanga and Bulacan area from the mudflats going inland (Figure 16). Mangrove areas as of 1990 cover around 2,000 ha; at present, it is estimated to be around 794 ha only. Meantime, mudflat combined with sandflat areas cover about 6,000 ha. These developments have significant impact on the effective surface area of the bay.

This is related to the shoreline changes around Manila Bay as reported by Siringan *et al.* in 1997.

Changes in the bottom topography and bathymetry of Manila Bay are interrelated. The decline is indicated by increasing deposition of sediments in the bottom of the bay and the depth changes, which indicated more shallowing, especially in the deeper portions of Manila Bay along the Bataan coast in Limay and Mariveles.

Whatever deepening that occurs in the bay is really just an interplay of three factors, i.e., the prevailing natural current system in the bay, the wind movement and the influx of freshwater, which shows that there is no real deepening, only a redistribution of sediment deposits at the bottom. The fact remains, however, that there is shallowing in almost all portions of Manila Bay.

The shallowing and sediment deposition in the bay is attributed to erosional forces along the bay's coastline which are mostly man-induced. This can be seen in the changes that occurred in the shoreline of Manila Bay as reported by Siringan *et al*. (1997).

**Table 17. Retrospective Analysis for Bathymetric Changes in Manila Bay.**

| Parameter | Areal Extent | Bathymetrical Changes Observed | | | Identified Agents | Impact |
|---|---|---|---|---|---|---|
| | | Depth | Shallowing | Deepening | | |
| Bathymetry | Large | one fathom | • Pilar, Bataan to the Pampanga River and Bay<br>• Manila Port Area up to Parañaque | • Hagonoy to Meycauayan, Bulacan to Navotas to North Manila<br>• Bacoor to Cavite City to Ternate, Cavite | Likely:<br>• Shallowing due to deposition of sediments and erosional forces as well as man-induced shoreline changes<br>• Deepening due to oceano-graphic forces such as currents and waves | • Damage to and destruction of various resources such as coral reefs, seagrasses and seaweeds and loss of habitat<br>• Damage to property<br>• Changes in species composition and distribution. |
| | | three fathoms | • Limay to Mariveles (Lamao to Cabcaben) in Bataan<br>• Orion, Bataan to Hagonoy, Bulacan | • In front of the Pasig River<br>• Parañaque to Las Piñas to Zapote to Bacoor<br>• Cavite City to Ternate, Cavite | | |
| | | five fathoms | • Limay to Mariveles (Lamao to Cabacaben) in Bataan<br>• Hagonoy to Paombong, Bulacan<br>• Manila to Pasay<br>• Southern Caballo Island | • Mouth of Pasig River<br>• Pasay to Zapote to Bacoor to Cavite City<br>• Naic to Ternate, Cavite<br>• Western Corregidor Island | | |
| | | 10 fathoms | • Limay to Mariveles (Lamao to Cabcaben) in Bataan<br>• Bulacan down to Cavite City | • Limay, Bataan to Bulacan to mouth of Pasig River<br>• Western Corregidor Island<br>• Western Caballo Island | | |

*Sources: BFAR, 1995.*

The probable causes include the increase in agricultural and aquacultural activities along the coast of the bay plus the continuous denudation of its watershed areas, which in turn, contributed significantly to the decline of marine resources in the bay and the worsening condition of its bottom topography and shallowing depth.

Inadvertently, changes in the bottom profile of the bay and its shallowing depth have detrimental impacts on the various resources around and within Manila Bay as it affects the integrity of the various ecological niches in the bay.

Table 17 shows a summary of the retrospective analysis for bottom topography and bathymetric changes in Manila Bay.

## 3.6. SUMMARY: RETROSPECTIVE ASSESSMENT

### 3.6.1. 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. Chlorophyll-a levels increased between the period of observation 1996-1998 (PRRP, 1999) but no definite correlation has yet been established between chlorophyll-a and phytoplankton density.

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

Table 18 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 have 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.

### 3.6.2. Habitats

For habitats (Table 19), clear evidence of decline was established only for mangroves (BFAR, 1995). From 54,000 ha of mangrove forests at the turn of the century (1890), only 2,000 ha were left in 1990 which was drastically reduced to 794 ha in 1995. For coral reefs, there were no records of the previous extent of cover but more recent studies and unpublished accounts suggest that there had been a decline in the quality and cover of the reefs. The present status of the coral reef resources of Manila Bay is generally classified as in poor to good condition. The average cover of living corals (both hard and soft) in Manila Bay

**Table 18. 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 - refers only to the market value of the resource* was estimated to be 40 percent or fair condition. 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 to 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 to 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 19 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 have 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 19. 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 - *refers only to the market value of the habitat*

# 4. PROSPECTIVE RISK ASSESSMENT

## 4.1. INTRODUCTION

Various methodologies and techniques for environmental risk assessment 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 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 RQ technique can be applied to prospective risk assessment in order 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 and comparing their MECs or PECs with appropriate threshold values or PNECs to get RQs. For human health, risk through seafood ingestion is estimated by comparing the MECs or PECs with the LOC, which in this case will be the TDI divided by the consumption rate.

From 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).

In considering human health effects or where man is directly the target, the main pathway considered is the ingestion pathway, although skin contact by bathing may be relevant for certain contaminants. Thus, the MECs or PECs in edible tissue of fish, shellfish or other seafood are used in estimating risks.

## 4.2. RQ-BASED RISK ASSESSMENT

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 (1999).

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 TDIs by the consumption rates. When the RQ is less than one, it is presumed that the likelihood of adverse effects is low. When the RQ is greater than one, there is a likelihood of adverse effects, the magnitude of which increases with increase in RQ.

RQs in this report are expressed as $RQ_{Geomean}$ or $RQ_{Max}$. The $RQ_{Geomean}$ was obtained by calculating the geometric mean of MECs from a

**For ecological risk assessment:**

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

**For human health:**

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

$$LOC = \frac{\text{Tolerable Daily Intake}}{\text{Consumption Rate}}$$

Where RQ $< 1$ Low risk
$\geq 1$ High risk

set of data and dividing it by the PNEC. The geometric mean MEC was preferred to the arithmetic mean MEC 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. The $RQ_{Max}$ gives an estimate of the worst or highest RQ based on a set of available data, by selecting the highest observed measured environmental concentration (MEC) and dividing it by the PNEC. Calculated RQs >1 in the data tables in this paper are in bold font so that these can be readily pinpointed.

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 or LOCs. The lack of Philippine values for PNECs or LOCs represents a major source of uncertainty in the risk assessment. Be that as it may, the utility of the RQs in signalling potential areas of concern is significant. The uncertainties were minimized through the careful selection of good quality data and relevant thresholds or these were 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 refined risk assessment of Manila Bay came primarily from the PRRP Report (PRRP 1999). A description of the data and sampling locations for PRRP and other references can be found in Appendix 3.

For ecological risk assessment, the RQ-based prospective risk assessment technique was considered adequate in determining risks posed by contaminants in the water column and sediment. The application of the threshold values or PNECs was based on the following scheme: the local criteria values, i.e., Water Quality Criteria for Coastal and Marine Waters in the Philippines, were initially applied. In the absence of local criteria values, the ASEAN Marine Water Quality Criteria (ASEAN, 2003) and criteria values from ASEAN countries were then applied. Subsequently, other tropical jurisdictions, e.g., Hong Kong interim sediment quality criteria, were applied. Finally, the criteria values from other jurisdictions, e.g., United States, were applied.

The Philippine criteria for coastal and marine waters were based on background levels and criteria limits of other jurisdictions. The ASEAN marine water quality criteria (ASEAN, 2003), while not yet officially adopted, were based on a comprehensive evaluation of toxicological data for a minimum of six tropical marine species and concentration levels prevailing in tropical environments. The criteria values were derived after the CCME method. The USEPA criteria are based on marine chronic and acute criteria for regulatory purposes.

For sediment quality, in the absence of locally derived criteria, the Hongkong Interim Sediment Quality Criteria (EVS Environment Consultants, 1996) were used.

Table 20 shows the PNECs applied for each of the parameters under consideration.

For human health risk assessment, the RQ-based prospective risk assessment was used as a screening tool to identify contaminants of concern, and for contaminants or toxicants where the RQ (either $RQ_{Geomean}$ or $RQ_{Max}$) is > 1, refinement of the risk estimates were made by calculating the actual

**Table 20. PNECs Used in Calculating RQs for Ecological Risk Assessment.**

| No. | Parameter | Matrix | PNEC Applied |
|---|---|---|---|
| 01 | Fecal and Total Coliform | Water column (bathing beaches) | Water quality criteria for coastal and marine waters (DAO 34/1990) |
| 02 | Heavy metals | Water column | -DAO 34/1990<br>- ASEAN marine water quality criteria<br>-US EPA marine chronic and acute criteria for regulatory purposes |
| | | Sediment | -Hong Kong interim sediment quality criteria value (HK ISQV)<br>-Shale values |
| 03 | Pesticides | Water column | US EPA marine chronic and acute criteria for regulatory purposes |
| | | Sediment | HK ISQV |
| | | | Shale values (for comparison) |
| 04 | Nutrients | Water column | ASEAN marine water quality criteria |
| 05 | Dissolved oxygen | Water column | DAO 34/1990 |
| 06 | Total suspended solids | Water column | Malaysian water quality criteria |
| 07 | Polyaromatic hydrocarbons | Sediment | HK ISQV |
| 08 | Oil and grease | Water column | DAO 34/1990 |

doses received (exposure assessment), which is discussed further in Sections 4.4 and 5.4. The source of the TDIs used in calculating RQs is shown in Appendix 4. One of the major difficulties associated with human health risk assessment is the lack of Philippine TDIs. Most, if not all, of the TDIs used were derived from foreign sources, particularly the USFDA. There are differences in the anatomical, metabolic and physiologic characteristics of the average Caucasian man and the average Filipino man.

It should be further recognized that the relative risks of contaminants to human health vary considerably. As an example, intake of even trace amounts of lead may be considered harmful to brain development in children, whereas intake of far more dramatic levels of coliform may be tolerated by the immune system. While it is assumed that the relative toxicity of contaminants are taken into consideration in the determination of appropriate TDIs, toxicity was again used as a parameter in comparing risks in order to prioritize risk management actions (Section 5.4.2).

Acute exposure versus chronic exposure to a contaminant will also affect the relative risks of contaminants depending on the toxicity, mode of action, and fate of the contaminant in the human body.

In comparing risks due to different contaminants, relative bioaccumulation potential and toxicity were scored and used together with the RQs in ranking risks from various contaminants in the Bay. A detailed discussion of the approach employed can be found in the section on Comparative Risk Assessment (Section 5.4.2).

Finally, the risk-based methodology was applied in the initial and refined risk assessment of Manila Bay as this is viewed to be a reasonable tool in environmental management, particularly when the resources are limited and there is a need to prioritize environmental concerns for risk management. It is recognized, however, that there are other approaches to environmental protection and management. One such approach is based on the precautionary principle.

## 4.3. PRECAUTIONARY PRINCIPLE

The precautionary principle was introduced in the early 1970s in Europe as a tool for decision-making on perceived environmental threats arising from processes or substances that had not undergone safety evaluation or on which there is paucity of data that will allow risk assessment of these processes or substances. The present practice of invoking this principle appears to have originated from Principle 15 of the Rio Declaration on Development and Environment (UNEP, 1992) which states that, "lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation.

Most, if not all, of the contaminants included in the refined risk assessment have been studied and their effects to the environment or to human health established. Thus, the risk assessment approach based on risk quotient (RQs) was considered adequate for purposes of providing risk managers with data and information that can be used in prioritizing practices and contaminants that pose relatively serious threat to human health and to the environment and that merit immediate attention. Comparative risk assessment of these contaminants can be a valuable tool in determining priorities for preventive and remediation strategies that will ensure the sustainability of Manila Bay, given the limited resources for risk management.

## 4.4. EXPOSURE ASSESSMENT

### 4.4.1. Introduction

The use of RQs in assessing risks to human health has limitations, as threshold values below which there appears to be no adverse effects have not been established for all of the contaminants included in the refined risk assessment. Most if not all, of the TDI values used were based on USFDA or international standards. In adopting these TDIs, it is assumed that relative toxicity, persistence and bioaccumulation, among others, are factored into the TDI. Further, most of the available TDI values are for adults whereas children are generally considered as the more sensitive group and their body weights are comparatively less than those of adults. Hence, the relative risks to children can be considerably higher. This is an important consideration in assessing and prioritizing the human health risks to certain contaminants such as heavy metals and more specifically lead, since lead is known to retard brain development.

Aside from the uncertainties introduced by the absence of age-specific, local TDIs that can be used in calculating RQs, actual exposure to these contaminants are inferred only through the use of average consumption rates without regard to sub-populations such as the coastal population that may consume more seafood. Every effort was made to use age-specific consumption rates, if these were available.

RQ analysis is used widely as a basis for ecological risk assessment in chemical control legislation. The risk quotient compares predicted exposure concentrations with predicted no-effects concentrations. These are often treated as single number indicators of risk but clearly involve uncertainties in both numerator and denominator. Despite these uncertainties, most risk quotients calculated for potential contaminants of Manila Bay, namely, pesticides, heavy metals, coliforms, PAHs and algal blooms have indicated the presence of imminent if not present harm to the Bays' ecological state. However, when the RQ is at or around one, the hazard that these toxicants pose directly to man requires further risk analysis in order to prioritize risk management actions, given the associated costs of these actions and limited resources. It stands to reason that toxicants for which the RQ >>1 deserve immediate attention for risk management even without the benefit of exposure assessment.

### 4.4.2. Rationale

Exposure assessment is the aspect of risk assessment that determines the actual level of exposure and absorption of toxicant among the population of exposed individuals.

A balance must be obtained between the risk that these toxicants cause and the benefits that man gain from them. There is no reason therefore to allow high concentration of coliform bacteria in the Bay unless nature has intended it to be a sewer. On the other hand, pesticides are allowed to exist because these control pests that can damage important food sources for man. The levels of exposure are measured based on the frequency and duration of exposure as well as the levels of contaminant in the exposure media such as soil, water, air and food. Actual absorption is determined by toxicological studies.

The level to which man may be exposed to contaminants depends upon the initial concentration at the source of contamination and its rate of distribution and dilution as it travels through air, water, soil and food. The chemical reactions which occur in the exposure media may render the agent more or less toxic than the original compound. Environmental fate studies provide information about the fate of chemicals in the environmental media and are used in exposure assessment for characterizing the exposure scenario.

For the refined risk assessment, four groups were selected as the population at risk from the effects of the contaminants present in the bay. These were pregnant women, lactating mothers, children and the general population.

$$\text{Exposure} = \frac{\text{concentration in tissue (mg/kg)} \times \text{intake (kg/day)} \times \text{duration (years)} \times \text{frequency (no. of intakes per year)}}{\text{body weight (kg)}}$$

This expresses milligram toxicant per kilogram body weight per day (mg/kg/day).

Based on the formula, the exposure of children is higher under the same conditions as adults due to differences in body weight.

Once concentration(s) in the environmental media at the point of contact with the target population has been established, the frequency and duration of exposure by members of the population are determined.

In calculating exposure, the following assumptions were made:

1. The four population groups have different intake or consumption rate for shellfish or fish from the Bay;

2. The concentration of toxicant is approximated by the amount of toxicant recovered through analysis per kg of food taken, whether this is fish or shellfish;

3. There is a daily consumption rate of the toxicant; and

4. The calculation does not consider initially the difference between intake and uptake.

Nevertheless, not all toxicants in Manila Bay pose the same danger to human lives. Furthermore, hazard or risk assumes different degrees of gravity and tolerability. Thus for toxicants where the RQ <<1, exposure assessment was not considered necessary. For RQ >>1, remedial measures are implied even without the benefit of exposure assessment.

Corollary to this is the need to characterize the risk on human lives by the different toxicants in the Bay. This will give direction to future plans for risk management by identifying which among the toxicants poses the greatest threat to man and society and therefore justify the costs of remediation.

## 4.5. COLIFORMS

### 4.5.1. Water Column

Monthly coliform measurements from 10 bathing beaches monitoring stations (Table 21), which were generally used for swimming or bathing, were analyzed. Water samples were collected at the eastern and southeastern section of the bay from 1996 to 1999 (PRRP, 1999). The coliform group of bacteria constitutes the principal indicator of the degree of contamination and thus sanitary quality of water bodies.

**Table 21. Bathing Beaches Monitored.**

| Station No. | Station Identification | Location |
|---|---|---|
| 1 | Navotas Fish Port | Bangkulasi, Navotas |
| 2 | Luneta Park | Luneta Grandstand, Manila |
| 3 | Bacoor | Bacoor, Cavite |
| 4 | Lido Beach Resort | Rosario, Cavite |
| 5 | Villamar Beach Resort | Rosario, Cavite |
| 6 | San Isidro Beach Resort | Rosario, Cavite |
| 7 | Celebrity Beach Resort | Tanza, Cavite |
| 8 | Garden Coast Beach Resort | Tanza, Cavite |
| 9 | Costa Eugenia Beach Resort | Naic, Cavite |
| 10 | Punta Grande Beach Resort | Naic, Cavite |

*Source: PRRP, 1999.*

The threshold value for Class SC as defined in the Water Quality Criteria for Coastal and Marine Waters is 5,000 most probable number (MPN)/100ml (total coliform) and for Class SB (fecal coliform) is 200 MPN/100ml (DAO 34, 1990). There were no values set for fecal coliform for Class SC. Class SB waters are those zoned for recreational purposes with direct skin contact and possibility of ingestion (swimming, bathing, diving, etc) and spawning areas for *Chanos chanos* or "bangus" while Class SC waters are those zoned for recreational purposes where the possibility of ingestion is minimal; i.e., boating, for commercial and sustenance fishing, and for marshy and /or mangrove areas declared as fish sanctuaries. Said standards refer to the geometric mean of the most probable number of coliform organisms during a three-month period.

The RQs for coliform were computed by dividing the monthly geometric mean by Class SB Standard of 200 MPN/100ml for fecal coliform and 5,000 MPN/100ml for total coliform.

Table 22 shows the calculated RQs for total and fecal coliform for the four-year period.

Based on the highest MEC for total coliform of 16,000,000MPN/100ml, the worst RQ was 3,200, which was observed at the Navotas Fish Port and Bacoor during the months of July 1997 and January 1999, respectively. The highest concentration of fecal coliform was also measured at the same stations, particularly Bacoor, during the month of December 1999 with a calculated $RQ_{Max}$ of 15,000.

$$RQ = \frac{MEC}{PNEC}$$

where MEC = 3-month geometric mean expressed in MPN/100 ml
PNEC = 200 MPN/100 ml (Fecal coliform) or
= 5,000 MPN/100 ml (Total coliform)

$$\text{Annual Mean } RQ_{geomean} \text{ per station} = \frac{\sum \text{monthly } RQ_{geomean}}{\text{number of months}}$$

and

$$\text{Annual Mean } RQ_{geomean} \text{ for MB} = \frac{\sum \text{Annual Mean } RQ_{geomean} \text{ per station}}{\text{number of stations}}$$

Table 23 shows that the calculated average $RQ_{Geomean}$ for fecal coliform in the whole bay has increased dramatically from 73 (1996) to 128 (1998). On the other hand, $RQ_{Geomean}$ for total coliform decreased from 11 in 1996 to four in 1998, but severely escalated to 20 in the year 1999.

The occurrence is caused by the upsurge of population in areas draining to Manila Bay. These high RQs pose a serious concern for human health. High coliform levels were mostly measured and detected in the southern part of Manila Bay, specifically in Manila which is the main source of the contaminant.

Seasonal variations were observed in that the average $RQ_{Geomean}$ for coliform appeared to be generally higher during the wet season than dry season (Table 24).

Figures 16-21 clearly show that the annual average $RQ_{Geomean}$ both for fecal and total coliform has increased in recent years (1998-99) in several areas. Further, the figures reveal that in general, the $RQ_{Geomean}$ during wet season is higher than dry season for both fecal and total coliform.

The high bacterial load may be attributed mainly to voluminous sewage and domestic

**Table 22. RQs of Total and Fecal Coliform in Manila Bay.**

| Coliform | $MEC_{Geomean}$ (MPN/100 mL) | $MEC_{Max}$ (MPN/100 mL) | PNEC (MPN/100 mL) | $RQ_{Geomean}$ | $RQ_{Max}$ |
|---|---|---|---|---|---|
| Total Coliform | 735,413(n=555) | 16,000,000 | 5,000 | **147** | **3,200** |
| Fecal Coliform | 175,331(n=555) | 3,000,000 | 200 | **877** | **15,000** |

*Source of MEC: PRRP, 1999.*
*Source of PNEC: DAO 34, s. 1990.*

**Table 23. Annual Coliform $RQ_{Geomean}$ in Manila Bay Bathing Beaches.**

| Station No. | Fecal Coliform $RQ_{Geomean}$ | | | | Total Coliform $RQ_{Geomean}$ | | | |
|---|---|---|---|---|---|---|---|---|
| | *1996* | *1997* | *1998* | *1999* | *1996* | *1997* | *1998* | *1999* |
| 1 | 440 | 107 | 397 | 210 | 41 | 32 | 9 | 19 |
| 2 | 117 | 31 | 235 | 337 | 48 | 19 | 20 | 75 |
| 3 | 20 | 18 | 94 | 376 | 7 | 4 | 9 | 86 |
| 4 | 14 | 8 | 123 | 5 | 0.9 | 2 | 0.5 | 1 |
| 5 | 11 | 28 | 49 | 8 | 1.2 | 3 | 0.5 | 2.2 |
| 6 | 44 | 27 | 103 | 40 | 3 | 5 | 1.7 | 4.3 |
| 7 | 61 | 44 | 224 | 39 | 5 | 9 | 1.1 | 2.8 |
| 8 | 9 | 8 | 28 | 74 | 1 | 3 | 0.4 | 6 |
| 9 | 4 | 4 | 16 | 10 | 0.6 | 2 | 0.4 | 1.2 |
| 10 | 6 | 8 | 6 | 12 | 0.5 | 1 | 0.3 | 1.1 |
| **Annual Mean** | 73 | 28 | 128 | 111 | 11 | 8 | 4 | 20 |

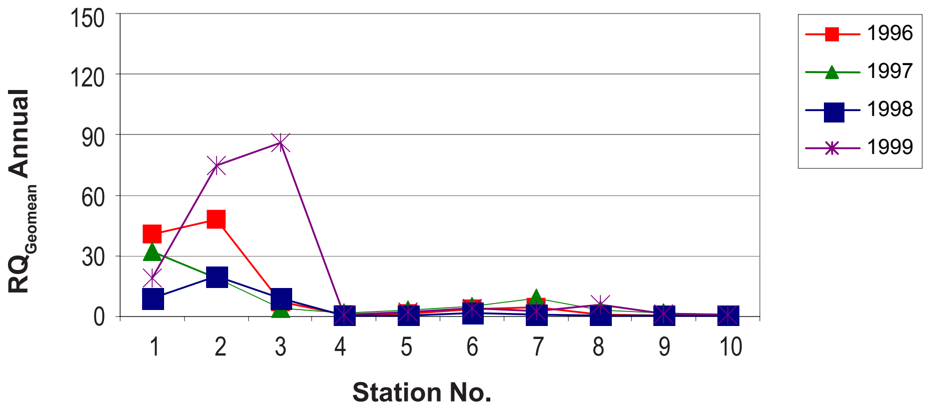
*Source of MEC: PRRP, 1999.*
*Source of PNEC: DAO 34, s. 1990.*

**Table 24. Seasonal Variation of $RQ_{Geomean}$ for Fecal Coliform**

| Year | $RQ_{Geomean}$ | |
|---|---|---|
| | Wet | Dry |
| 1996 | 80 | 62 |
| 1997 | 28 | 28 |
| 1998 | 125 | 122 |
| 1999 | 128 | 94 |
| **Average** | 90 | 77 |

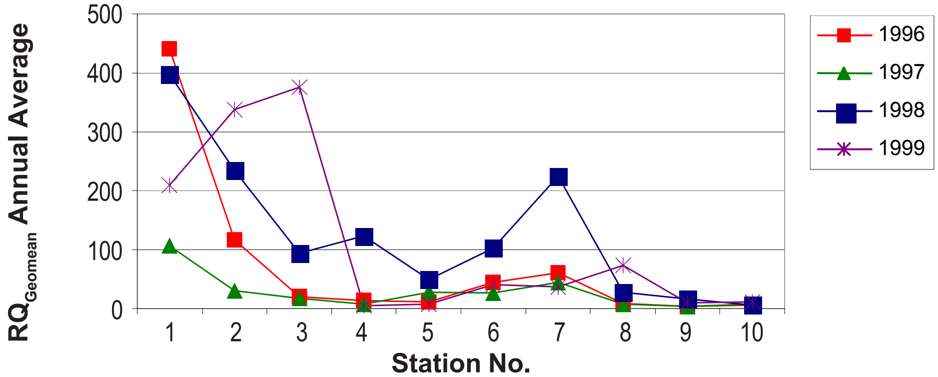
*Source of MEC: PRRP, 1999.*
*Source of PNEC: DAO 34, s. 1990.*

**Figure 16. Annual Total Coliform $RQ_{Geomean}$ in Monitoring Stations.**



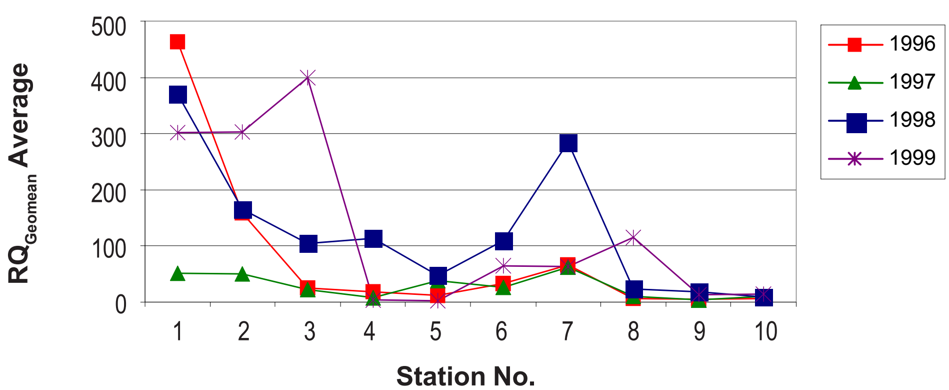

*Source: RQs computed using MECs from PRRP, 1999 and PNECs from DAO 34, s. 1990.*

**Figure 17. Annual Fecal Coliform $RQ_{Geomean}$ in Monitoring Stations.**




*Source: RQs computed using MECs from PRRP, 1999 and PNECs from DAO 34, s. 1990.*

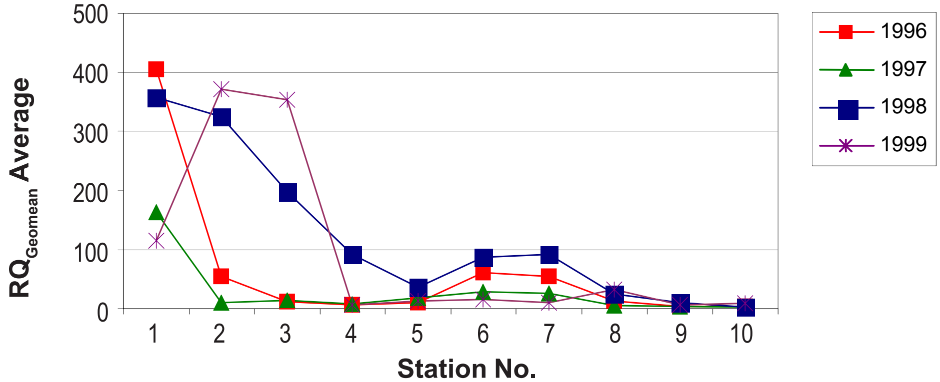
**Figure 18. Fecal Coliform $RQ_{Geomean}$ During the Wet Season.**




*Source: RQs computed using MECs from PRRP, 1999 and PNECs from DAO 34, s. 1990.*

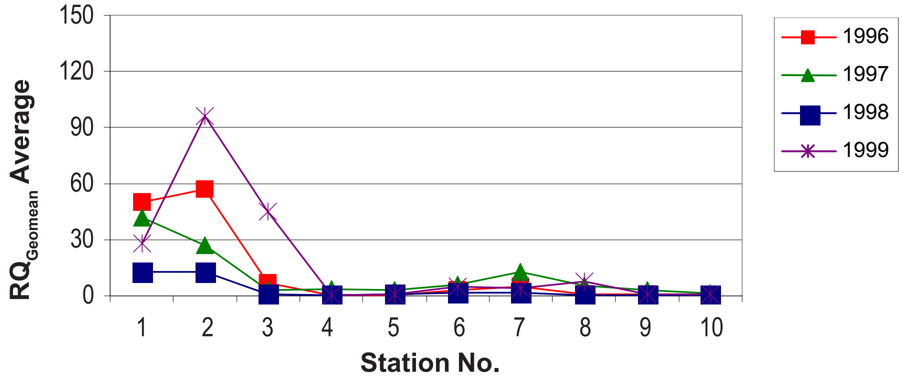
wastes generated from households that discharge directly to the bay or to the drainage and river systems, which eventually end up in the bay. Other sources include commercial and agricultural establishments such as slaughterhouses, markets, livestock farms, hospitals, and urban and rural run-off.

**Figure 19. Fecal Coliform $RQ_{Geomean}$ During the Dry Season.**



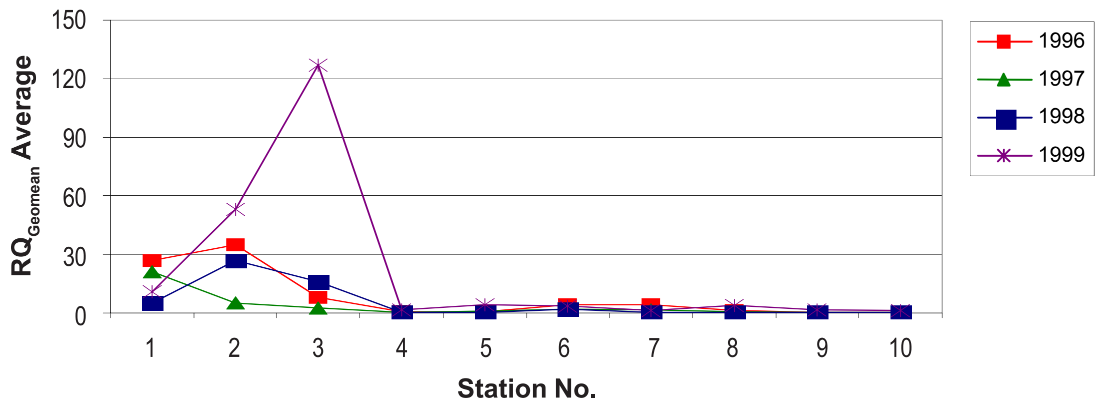

*Source: RQs computed using MECs from PRRP, 1999 and PNECs from DAO 34, s. 1990.*

**Figure 20. Total Coliform $RQ_{Geomean}$ During the Wet Season.**




*Source: RQs computed using MECs from PRRP, 1999 and PNECs from DAO 34, s. 1990.*

**Figure 21. Total Coliform $RQ_{Geomean}$ During the Dry Season.**




*Source: RQs computed using MECs from PRRP, 1999 and PNECs from DAO 34, s. 1990.*

### 4.5.2. Health Effects of Coliforms

Coliform bacteria are mostly non-pathogenic. They are found naturally in the intestines of warm-blooded animals, including humans. The concentration of coliform bacteria in water is used as an indicator of the presence of pathogens, which are normally found in human and animal excrete. This, in turn, is used to estimate the likelihood of contacting diseases from this water.

If drinking water is found to have concentrations of four or more coliform bacteria per 100 ml of water, corrective action is required. Counts higher than 2,300 are considered unsafe for swimming and counts exceeding 10,000 indicate that the water is unsafe even for boating.

The high bacterial load which can be attributed to voluminous sewage and domestic wastes generated from households discharged directly to the bay or to the drainage and river systems that eventually end in the bay, is hazardous to the health of the general public.

For the period 1996 to 1999, people bathing in beaches along the eastern portion of Manila Bay and in particular, Station 1 to Station 3, have relatively greater risk of becoming affected by fecal coliform in terms of skin itchiness or diarrhea, if the water is swallowed (Table 23). This is especially true during the wet season when the fecal coliform $RQ_{Geomean}$ is observed to be generally higher than during the dry season.

### 4.5.3. 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). Shellfish samples were collected from five shellfish sampling stations at the eastern portion of Manila Bay, namely: Bulacan; Bacoor, Kawit and Naic in Cavite; and Parañaque in Metro Manila for three consecutive years from 1996 to 1998. Shellfish samples were collected at least twice a year representing the dry and wet seasons. Species collected from the stations were mostly oysters except for Naic station where both oysters and mussels were collected, and Parañaque station where only mussel samples were gathered for analysis.

Based on the available data, the bacterial load in shellfish is a serious concern as well. There are no criteria values available for total coliform in shellfish. For fecal coliform in shellfish, the European Union limit of 300 MPN/100ml (EEC, 1979, cited in MPP-EAS, 1999b) as criteria was used in calculating $RQ_{Geomean}$. The fecal coliform geometric mean RQs for samples collected during the three-year period are shown in Figure 22. The highest $RQ_{Geomean}$ of 2,667 was obtained for oyster samples from Bacoor, Cavite collected during the wet season in 1998. For mussels, the highest annual $RQ_{Geomean}$ of 467 was obtained for samples collected from Paranaque in 1997. Most of the calculated RQs are below 300 but definitely much greater than one. The principal source of these bacteria is untreated domestic sewage.

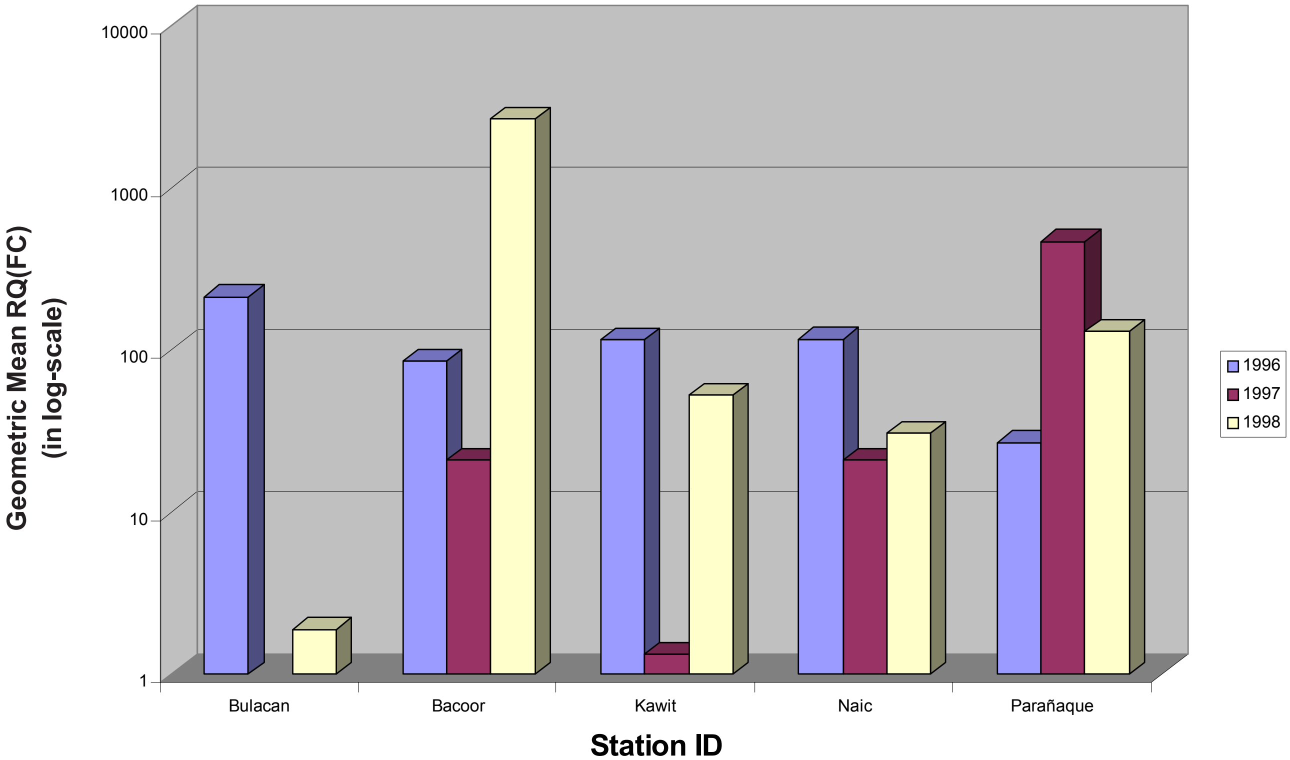
Based on the above information, exposed populations are at high risk from absorption or intake of fecal coliform from oysters and mussels harvested in the identified stations.

Seasonal effects on fecal coliform levels in shellfish tissue were also observed. This is clearly evident in Figure 23 which shows changes in fecal coliform levels between the dry and wet seasons. In general, the fecal coliform levels in shellfish tissues are higher during the wet season than during the dry season. The highest $RQ_{Geomean}$ of 2,667 and 1,000 were computed from oyster samples collected from Bacoor, Cavite and mussel samples collected from Parañaque, Metro Manila stations, respectively, during the 1998 wet season sampling.

**Uncertainty Analysis**

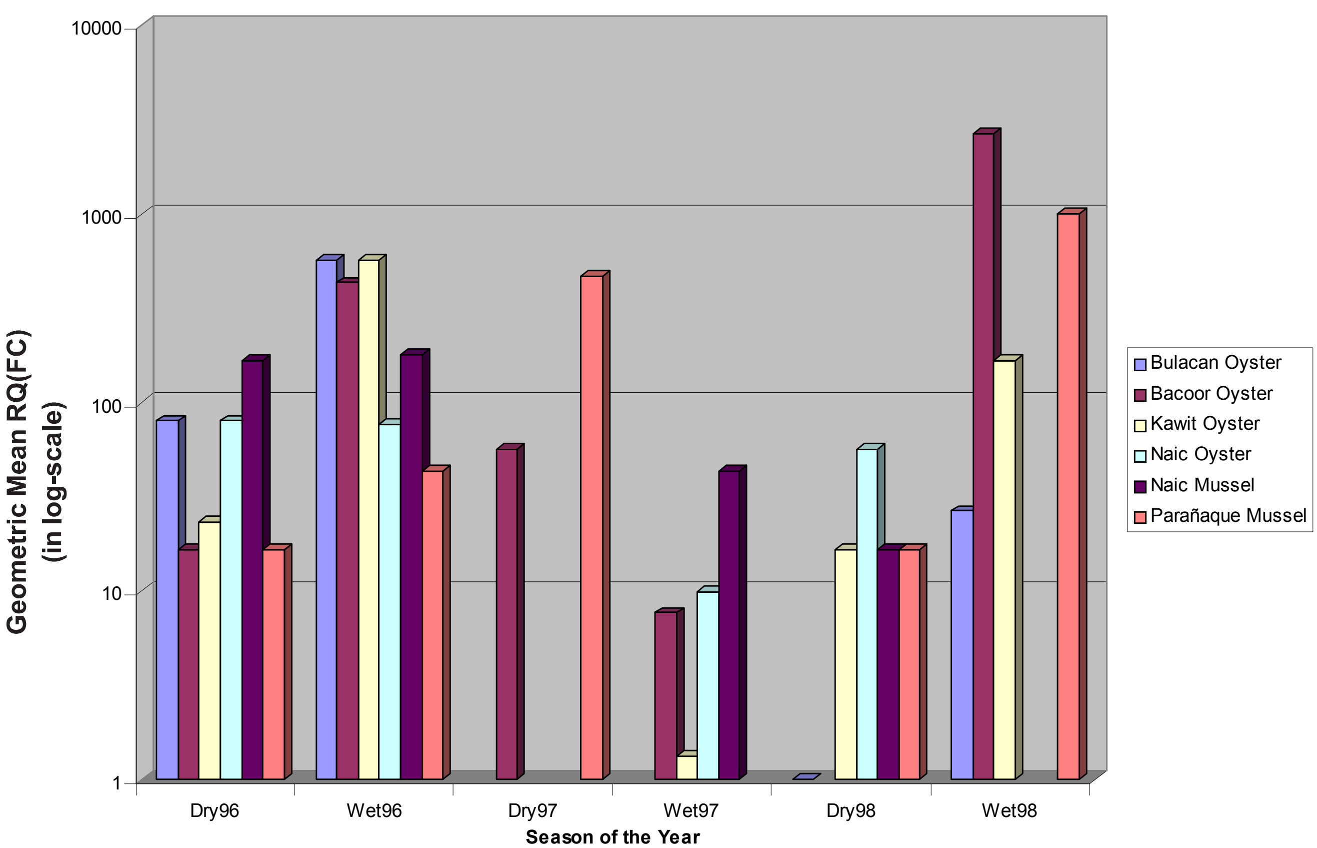
The risk assessment done on the water column was based only on data from the eastern section of the bay, the most populated and urbanized area around the bay. The project from which the data was derived focused on the monitoring of the water quality of bathing beaches, mostly found in the Cavite area. 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 to determine the extent of coliform contamination.

**Figure 22. Annual Fecal Coliform $RQ_{Geomean}$ in Shellfish Tissues Collected from Eastern Manila Bay.**




*Source: RQs computed using MECs from PRRP, 1999 and PNEC from DAO 34.*

**Figure 23. Seasonal Fecal Coliform $RQ_{Geomean}$ in Shellfish Tissues from 1996 to 1998.**




*Source: RQs computed using MECs from PRRP, 1999 and PNEC from DAO 34.*

Models can also be used to characterize the transport of coliform from outfalls and other sewage outlets particularly to other sections of the bay.

The data for coliform in shellfish tissue was also limited to a few sites at the eastern section of the bay although most, if not all of these sites are used for commercial growing of bivalves. The coliform levels in other bivalve-growing areas should be similarly monitored.

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.

## 4.6. HEAVY METALS

### 4.6.1. Water Column

Concentrations of several heavy metals were measured in water samples taken from 18 stations within the bay (Velasquez et al., 2002) and different river mouths (BFAR, 1995). Velasquez' work covered Cd, Cu and Zn and was undertaken in November 1998. In addition, data on lead and silver from the monitoring results of EMB (1991) were included. RQs for metals within the Bay were calculated using the following criteria values: DAO 34 (Philippines), ASEAN Marine Water Quality Criteria, and the US EPA water quality criteria (marine chronic criteria) for regulatory purposes, which are the most conservative among the different criteria or PNECs. It is noted that the criteria values for Cd are almost identical (i.e., approx. 10 μg/L) in the three jurisdictions (i.e., the Philippines, ASEAN, and the USA). For lead, the criteria values in ASEAN and the USA are identical at 2.9 μg/L but the Philippines adopted a much higher criteria value of 50 μg/L. The Philippines did not adopt a criteria value for Zn while the ASEAN proposal as well as that adopted by the US EPA were almost identical at 50 and 55 μg/L, respectively.

The calculated RQs for the heavy metals in the water column are shown in Table 25.

Table 25 shows that all RQs for metals in water are well below one for the three PNEC values applied. No significant trend could be discerned from the distribution of RQs vertically at different depths in the water column although differences in the horizontal distribution at the same depth were observed. For Cd, relatively high RQs were observed towards the bay's western section facing Bataan at a depth of 20 m. At 10 m and on the surface, relatively high Cd RQs were observed near the center of the bay. For Cu, relatively high RQs were observed near the center of the bay at all depths. For Zn, relatively high RQs were observed near the center of the bay at a depth of 20 m; at 10 m, relatively high RQs were observed towards the South Channel while on the surface, relatively high RQs were observed towards the northern portion of the bay facing Pampanga.

Of the three metals, Cu exhibited the highest RQs (although still less than one with a maximum value of 0.566) followed by Zn and finally, by Cd.

Table 26 shows the RQs of heavy metals in river mouths in Manila Bay. The RQs were derived using DAO 34 (Philippines) and the more conservative US EPA water quality criteria for regulatory purposes, particularly the marine chronic criteria.

For water samples taken from the river mouths during two sampling periods (September to

**Table 25. RQs of Heavy Metals in the Water Column.**

| Heavy Metal | MEC Geomean (µg/L) | MEC Max (µg/L) | DAO (Philippines) | | | ASEAN MWQC | | | US EPA marine chronic critera | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | PNEC (µg/L) | RQ Geomean | RQ Max | PNEC (µg/L) | RQ Geomean | RQ Max | PNEC (µg/L) | RQ Geomean | RQ Max |
| *Samples taken at 1 m-depth* | | | | | | | | | | | |
| Cd (n=17) | 0.03 | 0.14 | 10 | 0.003 | 0.014 | 10 | 0.003 | 0.014 | 9.3 | 0.003 | 0.015 |
| Cu (n=16) | 0.24 | 0.91 | 50 | 0.005 | 0.018 | 8 | 0.030 | 0.1140 | 2.9 | 0.080 | 0.310 |
| Zn (n=17) | 0.78 | 4.04 | - | - | - | 50 | 0.016 | 0.081 | 55 | 0.014 | 0.073 |
| Pb | 0.60 | 0.80 | | | | | | | 5.6 | 0.107 | 0.143 |
| Ag | 0.04 | 0.05 | | | | | | | 2.3 | 0.017 | 0.022 |
| *Samples taken at 10 m-depth* | | | | | | | | | | | |
| Cd (n=12) | 0.03 | 0.33 | 10 | 0.003 | 0.033 | 10 | 0.003 | 0.033 | 9.3 | 0.003 | 0.035 |
| Cu (n=13) | 0.38 | 1.64 | 50 | 0.008 | 0.033 | 8 | 0.047 | 0.205 | 2.9 | 0.131 | 0.566 |
| Zn (n=13) | 0.76 | 8.25 | - | - | - | 50 | 0.015 | 0.165 | 55 | 0.014 | 0.150 |
| *Samples taken at 20-m depth* | | | | | | | | | | | |
| Cd (n=12) | 0.02 | 0.06 | 10 | 0.002 | 0.006 | 10 | 0.002 | 0.006 | 9.3 | 0.002 | 0.006 |
| Cu (n=13) | 0.16 | 1.22 | 50 | 0.003 | 0.024 | 8 | 0.02 | 0.152 | 2.9 | 0.055 | 0.421 |
| Zn (n=13) | 0.54 | 1.48 | - | - | - | 50 | 0.001 | 0.030 | 55 | 0.010 | 0.027 |

*Source of MECs:* *Velasquez et al., 2002*
*EMB-DENR, 1991*

*Source of PNECs:* *DAO 34, s. 1990; ASEAN, 2003; and US EPA, 2000.*

**Table 26. RQs of Heavy Metals in River Mouths.**

| Heavy Metals | MEC Geomean (µg/L) | MEC Max (µg/L) | DAO 34 (Philippines) | | | U.S. EPA marine chronic criteria | | |
|---|---|---|---|---|---|---|---|---|
| | | | PNEC (µg/L) | RQ Geomean | RQ Max | PNEC (µg/L) | RQ Geomean | RQ Max |
| Cadmium | 0.8 | 1.6 | 10 | 0.080 | 0.16 | 9.3 | 0.09 | 0.17 |
| Copper | 4.9 | 46.5 | 50 | 0.098 | 0.93 | 2.9 | 1.70 | 16.00 |
| Lead | 13.2 | 13.8 | 50 | 0.260 | 0.28 | 5.6 | 2.40 | 2.50 |
| Mercury | 0.6 | 1.0 | 2 | 0.300 | 0.50 | 0.025 | 24.00 | 40.00 |
| Zinc | 26.0 | 42.5 | - | - | - | 55 | 0.47 | 0.77 |

*Source of MEC:* *BFAR, 1995.*
*Source of PNEC:* *DAO 34, s. 1990; US EPA, 2000*

October 1992 and February to March 1993), the highest concentrations of Cu and Pb were found in Cavite, mercury (Hg) and Zn in Pampanga, and Cd in Metro Manila. These metal concentrations were higher than the concentrations inside the bay, suggesting that the contribution of land-based human activities which lead to the release of metals which, in turn, are eventually transported into the bay through the rivers, is a major source of metals in the bay.

However, when the Philippine DAO 34 criteria for Class C water was applied, all the calculated maximum RQs are still below one, with the highest RQ of only 0.93 for Cu. The maximum RQ, however, jumped to 16 for copper when the more stringent US EPA marine chronic criteria was used as PNEC.

A marked increase in RQs was also evident in the case of Hg. With the Philippine criteria as

PNEC, both $RQ_{Geomean}$ and $RQ_{Max}$ for Hg were below one; however, with the US EPA criteria as PNEC, the $RQ_{Geomean}$ and $RQ_{Max}$ markedly increased to 24 and 40, respectively.

For Pb, $RQ_{Max}$ was only 0.28 when the Philippine PNEC was used, but it increased to 2.5 when the US EPA marine chronic criteria was used as PNEC. In the same manner, the $RQ_{Geomean}$ for Pb was only 0.26 with the Philippine PNEC but 2.4 with the US EPA criteria as PNEC.

The results give an indication of the range of RQs that would be obtained if criteria values that differ in degree of protectiveness were used. It will be useful if the Philippine criteria (DAO 34) for these heavy metals in the water column were reviewed, considering that the Philippine criteria are at least an order of magnitude higher than the US EPA criteria.

**Uncertainty Analysis**

The data generated by Velasquez *et al.* (2002) have been assigned a score of one for data quality. This implies a relatively high degree of confidence in the RQ values obtained for metals in Manila Bay waters.

The data generated for heavy metals in the water column (BFAR, 1995) have been assigned a score of three for data quality. Despite this, the data values were included in the RRA in the absence of any other data sets.

The RQs for heavy metals in Manila Bay waters, with the possible exception of Pb and Hg, indicate low concern for this parameter although limited data (particularly in terms of temporal scale) was used for the risk assessment. The RQs obtained from heavy metals in the river samples using two sets of criteria also demonstrate the uncertainty associated with the values used as PNECs.

### 4.6.2. Sediment

The data used for heavy metals in sediment was obtained from the work of Duyanen (1995). Duyanen's extensive study consisted of analysis of heavy metals in sediment from 164 sampling stations within Manila Bay that included the coast, the river mouths, and the deeper central areas. Heavy metals in this context refer to the total leachable metal concentrations which approximate the concentration of the mobile or potentially bioavailable metal phases hosted by the fine-grained sediments (i.e., particle size <2 μm). The use of total metal concentrations for bulk or granulometrically fractionated sediments as a measure of sediment-based pollution is not advisable, as the total also includes the metal concentrations of the immobile phases associated to crystalline sediment particles, which are commonly environmentally benign.

For the assessment, two sets of PNECs were used: (1) average shale values were adopted as PNECs for Cd, chromium (Cr), cobalt (Co), Pb, Hg, nickel (Ni), and Zn, whereas, the 120 mg/kg PNEC for Cu was adopted from Duyanen and Siringan (1998); and (2) HK ISQV for Cd, Cr, Co, Cu, Pb, Hg, Ni, and Zn. HK ISQV consisted of two criteria values, i.e., a low and an upper limit for each of the heavy metals assessed. The HK ISQVs were used in Hong Kong to classify sediments as uncontaminated (data < low limit), moderately contaminated (upper limit > data > low limit), and highly contaminated (data > upper limit). In general, the more stringent low limit was used in calculating RQ. If the calculated RQ is greater than one, the upper limit was then applied. If the calculated RQ still exceeded one, risk management action for that heavy metal is indicated.

Following the approaches of studies done on water and sediment systems in Europe, the employment of average shale values of Turekian and Wedepohl (1961) as baselines can be a good approximation for geogenic metal concentrations in sediments in the absence of cores age-dated back to pre-industrial sediment deposition. Initial results of several ongoing studies at the National Institute of Geological Sciences of the University of the Philippines focused on the derivation of metal baselines for Philippine sediments using dated core samples (Duyanen and Siringan, 1998; Duyanen *et al.*, 1999, 2000; Jaraula et al., 1999, 2000; Siringan *et al.*, 2000). The results suggest that Philippine pre-industrial concentrations of metals in the sediments of Manila Bay, Laguna Lake and Lingayen Gulf approximate those of the average shale, except for Cu, which yielded higher geogenic concentrations (120 mg/kg), and Cr, Co, and Ni, which show significantly lower geogenic concentrations relative to the average shale concentrations.

Sediment quality criteria are usually expressed as the concentration of an agent in sediment that will not pose unacceptable risks to benthic organisms or their use (US EPA, 1991). Sediment criteria are useful to: (1) provide a basis for more informed decisions on the environmental impacts of contaminated sediments; (2) serve as a guide in site monitoring applications; and (3) serve as a preventive tool to ensure that point and nonpoint sources of contamination are controlled in order to protect and preserve uncontaminated sediments. Between the shale values and sediment quality criteria, the use of the latter as PNEC is less restrictive and can be considered as adequate, since the shale values represent baseline values which may not necessarily be the values above which benthic organisms may face unacceptable risks.

#### 4.6.2.1. Spatial Distribution and Sources of Heavy Metals in the Sediments of Manila Bay

Of the metals analyzed, lead and zinc gave the best scenarios in terms of the bay-wide distribution of metals. Their lateral distribution patterns define the coastal Metro Manila, covering about five percent of the bay's total area, as depositional area for sediments with very high metal loads. There is pronounced metal concentration gradation from this coastal Metro Manila area towards the Bataan-Pampanga areas, delineating that the fine sediments with very low metal load underlie the rest of the Bay. Since the sediment data included coastal Metro Manila sediment where the metal loads are high, the $RQ_{Max}$ are greater than one for all metals with the exception of Ni, regardless whether the more conservative shale values or HK ISQV are used as PNECs (Table 27). However, the $RQ_{Geomean}$ exceeded one only for Cd, Pb and Zn when the shale values are applied while the $RQ_{Geomean}$ exceeded one only for Cu and Hg with the HK ISQV.

The scenarios, however, change when only the sediments of coastal Metro Manila area, defined from the distribution patterns of Pb and Zn, are considered in the $RQ_{Geomean}$ calculation. The $RQ_{Geomean}$ are higher for all the metals particularly Cd, Pb and Zn than those shown in Table 27 and the $RQ_{Geomean}$ for Cu and Hg now exceed one when the conservative shale values are used. (Table 28). Because of the extremely high concentrations of Pb and Zn in the sediments of coastal Metro Manila, the $RQ_{Geomean}$ calculated for the whole bay is enhanced by them, giving an erratic signal that the sediments of the whole bay maybe enriched in Pb and Zn, while, in fact, only the coastal Metro Manila area, i.e. about five percent of the total bay area, has sediments with high Pb and Zn loads. The $RQ_{Geomean}$ for Pb and Zn increased twofold of their whole bay $RQ_{Geomean}$ when calculated only for the coastal Metro Manila area. This reveals that the sediment-based RQ values, in order to be accurate in this case, should be interpreted with the lateral distribution patterns of the metals.

The sampling locations where high $MEC_{Geomean}$ values were obtained for the metals can be considered as source points or areas of pollution if they are categorized as sinks. The spatial

**Table 27. RQs of Heavy Metals in Sediments (<2μm) in Manila Bay.**

| Heavy Metal | $MEC_{Geomean}$ *(mg/kg)* | $MEC_{Max}$ *(mg/kg)* | Shale Value | | | Hong Kong Interim Sediment Criteria Value | | |
|---|---|---|---|---|---|---|---|---|
| | | | PNEC *(mg/kg)* | $RQ_{Geomean}$ | $RQ_{Max}$ | PNEC *(mg/kg)* | $RQ_{Geomean}$ | $RQ_{Max}$ |
| **Cadmium** | 0.04 *(n=164)* | 2.55 | 0.04 | 1.00 | 63.75 | 1.5 | 0.03 | 1.70 |
| **Chromium** | 30.08 *(n=164)* | 153.97 | 90 | 0.33 | 1.71 | 80 | 0.38 | 1.92 |
| **Cobalt** | 17.20 *(n=164)* | 38.31 | 19 | 0.90 | 2.02 | - | - | - |
| **Copper** | 110.84 *(n=148)* | 410.92 | 120* | 0.92 | 3.42 | 65 | 1.70 | 6.32 |
| **Lead** | 23.85 *(n=164)* | 264.05 | 20 | 1.19 | 13.20 | 75 | 0.32 | 3.52 |
| **Mercury** | 0.36 *(n=164)* | 3.60 | 0.5 | 0.72 | 7.20 | 0.28 | 1.28 | 12.86 |
| **Nickel** | 24.34 *(n=164)* | 59.93 | 68 | 0.36 | 0.88 | 40 | 0.61 | 1.50 |
| **Zinc** | 173.27 *(n=136)* | 1,465.01 | 95 | 1.82 | 15.42 | 200 | 0.87 | 7.32 |

*Source of MEC: Duyanen, 1995.*
*Source of PNEC (shale values): Turekian and Wedepohl, 1961.*
*Source of PNEC (HK ISQV): EVS Environmental Consultants, 1996.*
** Data from a dated sediment core from Laguna Lake (Duyanen and Siringan, 1998)*

**Table 28. RQs of Heavy Metals in Sediments (<2μm) for the Coastal Metro Manila Area as Delineated by the Distribution Patterns of Lead and Zinc Concentrations.**

| Heavy Metal | $MEC_{Geomean}$ *(mg/kg)* | $MEC_{Max}$ *(mg/kg)* | Shale Value | | | Hong Kong Interim Sediment Criteria Value | | |
|---|---|---|---|---|---|---|---|---|
| | | | PNEC *(mg/kg)* | RQ Geomean | $RQ_{Max}$ | PNEC *(mg/kg)* | RQ Geomean | $RQ_{Max}$ |
| Cadmium | 0.07 *(n=29)* | 2.55 | 0.04 | **1.75** | **63.75** | 1.5 | 0.05 | **1.70** |
| Chromium | 37.26 *(n=29)* | 153.97 | 90 | 0.41 | **1.71** | 80 | 0.47 | **1.92** |
| Cobalt | 15.91 *(n=29)* | 28.08 | 19 | 0.83 | **1.48** | - | | |
| Copper | 127.78 *(n=29)* | 410.92 | 120* | **1.00** | **3.42** | 65 | **1.96** | **6.32** |
| Lead | 54.10 *(n=29)* | 264.05 | 20 | **2.70** | **13.20** | 75 | 0.72 | **3.52** |
| Mercury | 0.68 *(n=29)* | 3.60 | 0.5 | **1.36** | **7.20** | 0.28 | **2.43** | **12.86** |
| Nickel | 24.80 *(n=29)* | 59.93 | 68 | 0.36 | 0.88 | 40 | 0.62 | **1.50** |
| Zinc | 317.79 *(n=29)* | 1,465.01 | 95 | **3.34** | **15.42** | 200 | **1.59** | **7.33** |

*Source of MEC: Duyanen, 1995.*
*Source of PNEC (shale values): Turekian and Wedepohl, 1961.*
*Source of PNEC (HK ISQV): EVS Environmental Consultants, 1996.*
** Data from a dated sediment core from Laguna Lake (Duyanen and Siringan, 1998)*

distribution of RQs of metals in the bay sediment based on HK ISQV as PNEC, are shown in Figures 24 to 32. Sediment from the mouths of the Malabon-Navotas and the Parañaque Rivers have the highest MECs, certainly indicating that these rivers are point sources of metals for the bay. Cd, Hg, Zn, Pb, and Ni are highest in the sediment taken from the mouth of Malabon-Navotas River, the concentrations of which are included among the MECs in Table 28. On the other hand, mouth sediment of the Parañaque River yielded the highest Cr and Cu MECs for the bay with the maximum values of 153.97 and 410.92, respectively. Pasig River also contributes sediment with high metal loads into the bay. However, in terms of RQs using the less stringent HK ISQV instead of the shale values as PNEC, the RQs are less than one for cadmium except at the station near the mouth of Malabon-Navotas River ($RQ_{Max}$ = 1.7) and another station near the Parañaque river mouth (RQ = 1.1) (Figure 24). For chromium, RQ > 1 was more pronounced in Bulacan River, an area associated with tanneries which is a potential Cr source, and in Paranaque River (Figure 25). For Cu, RQs exceeded one for the whole bay when the lower limit of the HK ISQV was used, with the high RQs found directly north and south of Manila, particularly near Pasig and Parañaque Rivers, and at the southwestern part of the bay near Mariveles, Bataan (Figure 26). When the background value obtained using a sediment core from the bay was used as PNEC, RQs exceeded one for areas near major rivers such as Pampanga, Malabon-Navotas, Pasig, Bulacan and Parañaque Rivers and the port area in Manila, naval base in Cavite and area near Mariveles, Bataan (Figure 27), strongly indicating potential sources of Cu entering the bay. The background value for Cu from a dated sediment core obtained from the bay may be more suitable as PNEC than the value from the HK ISQV. In terms of spatial distribution, Hg appears to be most problematic among the heavy metals. For Hg, RQ > 1 were observed in most areas, when the low limit of HK ISQV was used as PNEC (Figure 28). Jewelry-making may be one of the major contributors of Hg in the bay. When the upper limit of HK ISQV is used as the PNEC, the hot spots are reduced to a few places in Manila (central eastern Manila Bay) as shown in Figure 29. For Ni, the RQs were <1 except at areas near Pampanga River, Bulacan, and Navotas (Figure 30). Hot spots for Pb were observed in the eastern section of the bay particularly near Pasig and Parañaque Rivers (Figure 31). When the shale values instead of the HK ISQV are used as PNEC, Pb appeared to be even more widespread in the bay. RQs > 1 for Zn were observed in certain areas in the central and lower eastern side of the Bay only with the HK ISQV, with the highest RQs found in the mouths of Pasig and Parañaque Rviers. However, when the shale value for Zn is applied, RQs > 1 were more widespread in the bay.

The surfer plots indicated that Hg is the heavy metal of concern in sediment based on RQs. When the more stringent shale values are used as PNEC, Zn followed by Pb and Hg had hotspots in the bay as indicated by RQs > 1. Hotspots for copper were also identified with the use of the background value, which is two times higher than the HKISQV, as PNEC.

**Uncertainty Analysis**

Heavy metals data used in this assessment were assigned a score of two for data quality since

**Figure. 24. RQs for Cadmium in Sediment Based on HK ISQV (Lower Limit).**

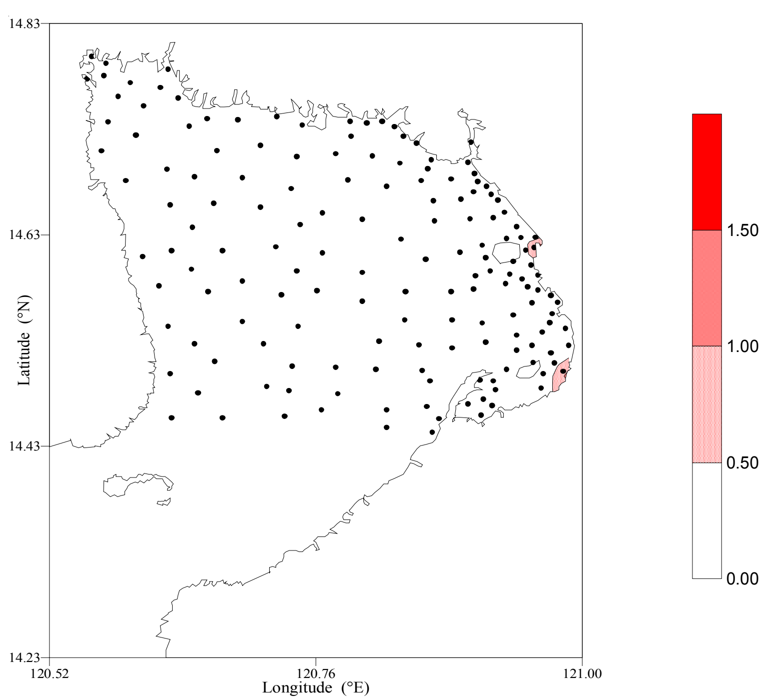


**Figure 25. RQs for Chromium in Sediment Based on HK ISQV (Lower Limit)**

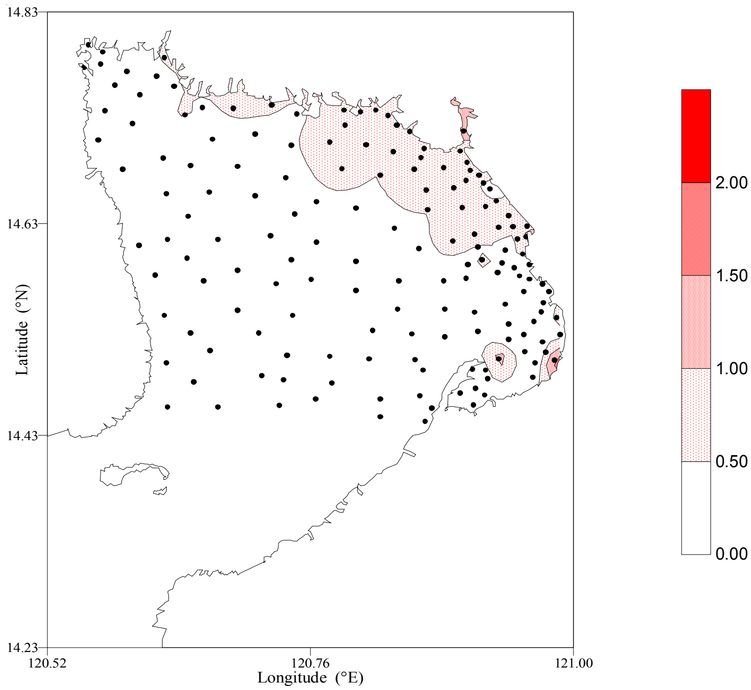



**Figure 26. RQs for Copper in Sediment Based on HK ISQV (Lower Limit).**

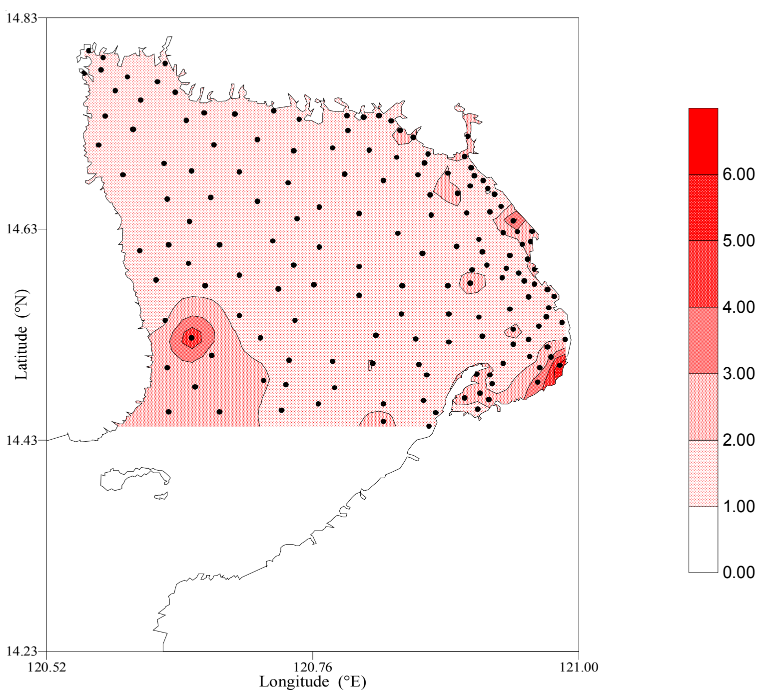


**Figure 27. RQs for Copper in Sediment Based on Baseline Value from a Dated Sediment Core Sample.**

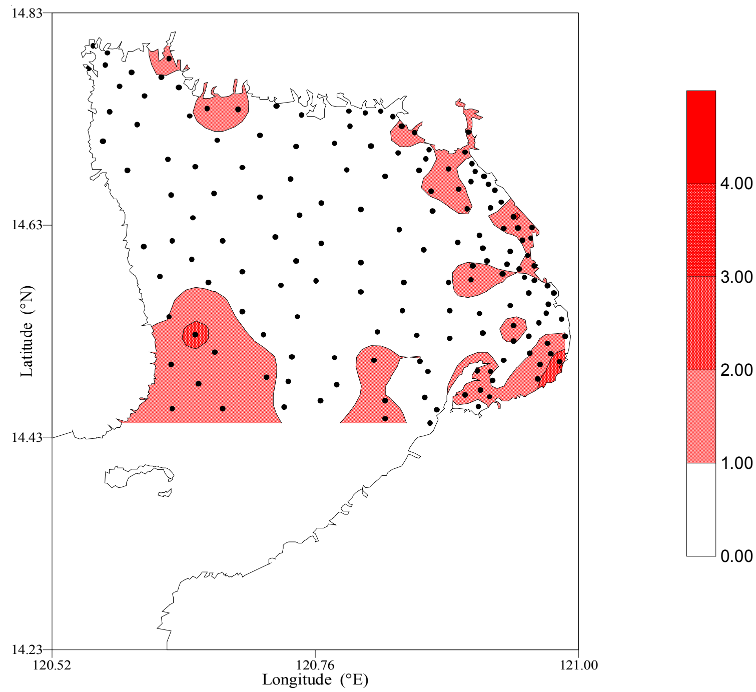



**Figure 28. RQs for Mercury in Sediment Based on HK ISQV (Lower Limit).**

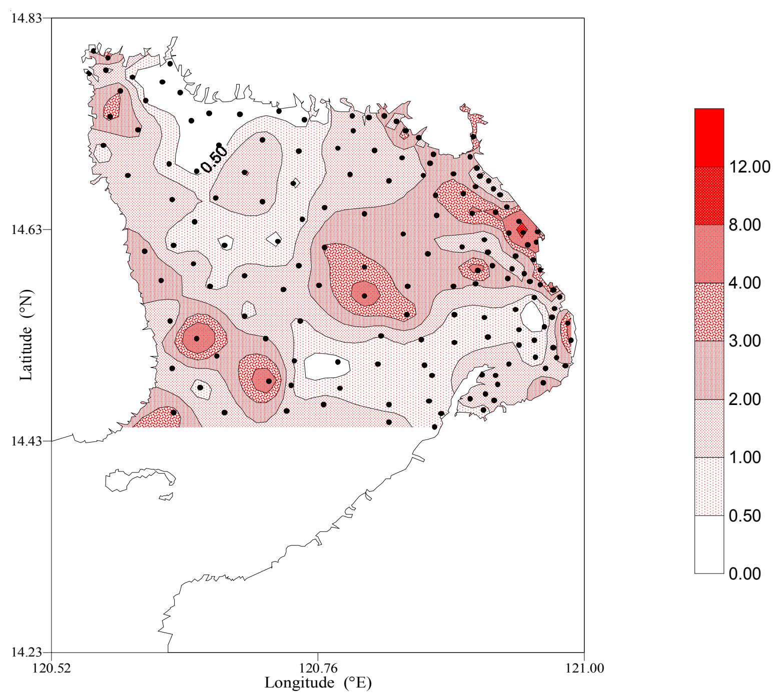


**Figure 29. RQs for Mercury in Sediment Based on HK ISQV (Upper Limit).**

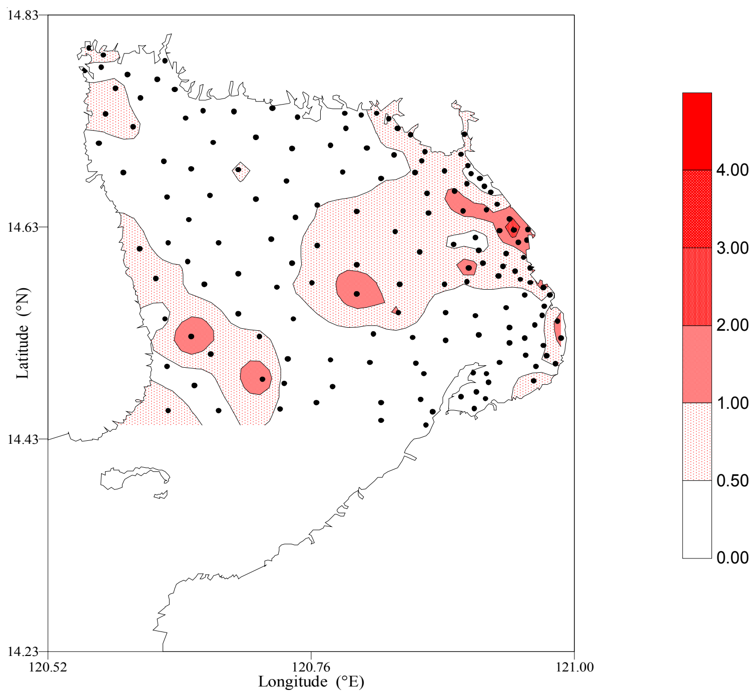



**Figure 30. RQs for Nickel in Sediment Based on HK ISQV (Lower Limit).**

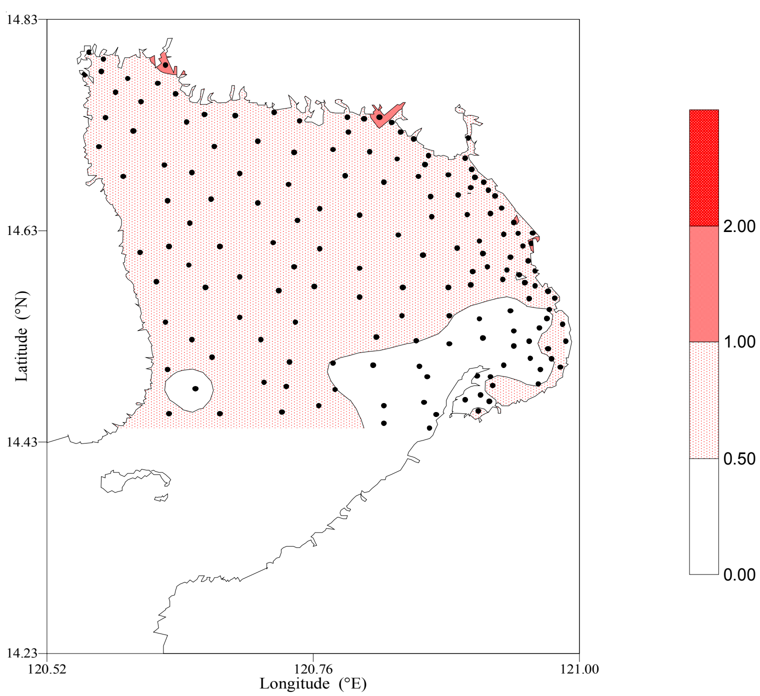


**Figure 31. RQs for Lead in Sediment Based on HK ISQV (Lower Limit).**

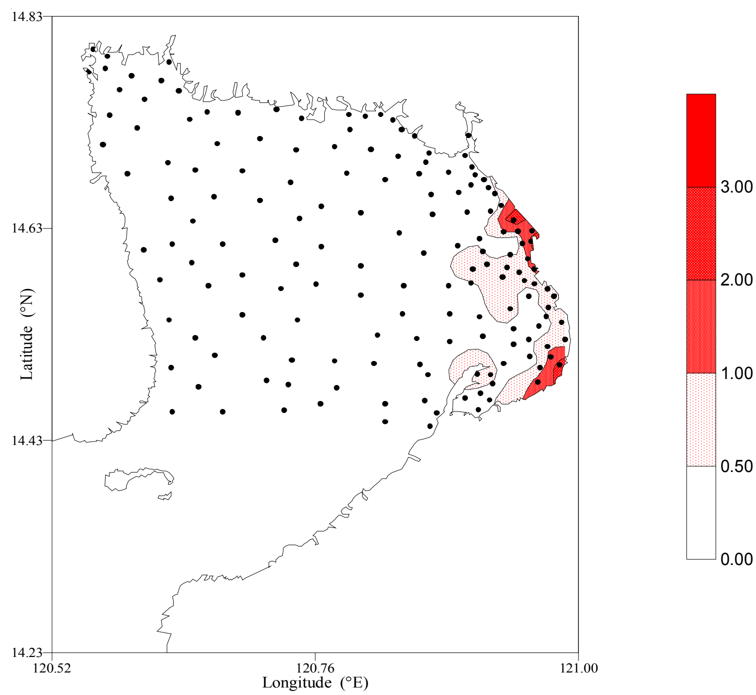
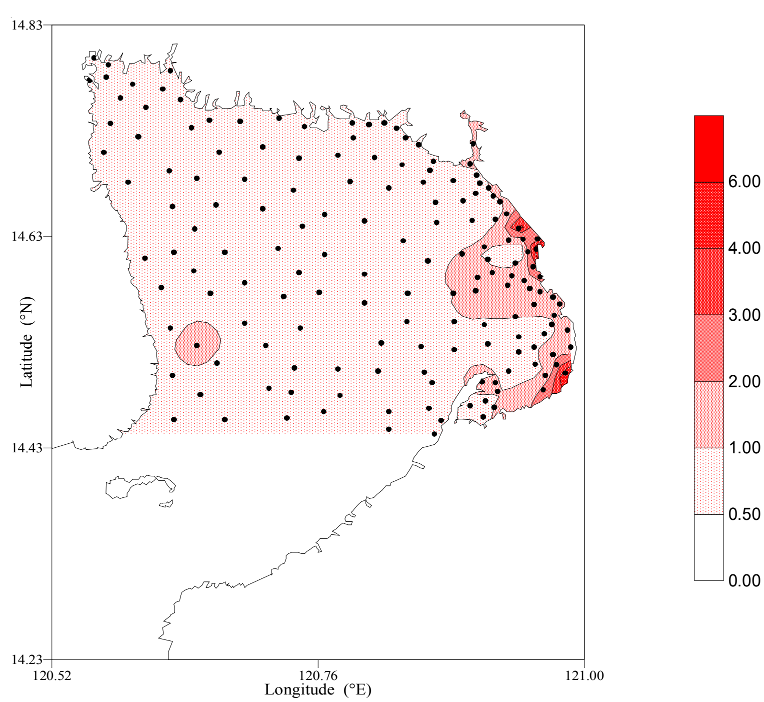



**Figure 32. RQs for Zinc in Sediment Based on HK ISQV (Lower Limit).**



QA/QC procedures were not specified in the documentation. Except for Cr and Ni, the heavy metals exhibited high certainty (21-100 percent) that the critical RQ level was exceeded.

### 4.6.3. Tissues

The data on shellfish tissue were taken from the PRRP report (1999) and FSP-REA/BFAR (1993) while the data on fish tissue was from the report of Prudente *et al.* (1997). The data from EMB-DENR were not included since it had been collected from a tributary river and the sampling/ measurement was done only once.

For the LOCs, the TDI values were taken from the MPP-EAS (1999b), which used TDI values for non-essential metals such as arsenic (As), Cd, Hg, Ni and Pb. These TDI values were adopted from the United States Food and Drug Administration (US FDA) and the recommended daily allowances (RDA) for essential metals (Cu, manganese (Mn), Zn and Iron) were from commercial nutritional supplements (MPP-EAS, 1999b). For essential metals, RDA was used because TDIs for essential metals are not available. In using RDAs for essential metals, it should be noted that an RQ greater than one is less likely to cause a risk to human health than an RQ of one for a non-essential metal.

Most, if not all, of the catch from Manila Bay are consumed by populations in areas around Manila Bay. For purposes of the refined risk assessment, the areas considered therefore are Metro Manila, Southern Tagalog and Central Luzon. It was assumed that communities from the three regions have more ready access to food products harvested in Manila Bay and are therefore more likely to obtain their food from Manila Bay. In calculating the RQs, the average consumption rate of fish used are 80 g/person/day for Metro Manila and Southern Tagalog and 69 g/person/ day for Central Luzon (FNRI, 1993). The calculated RQs can apply equally to the general population, inasmuch as the national average consumption rate of fish is close to 80 g/person/day. As a further refinement of the RQ-based technique, average consumption rates specific to relatively sensitive populations, such as the lactating mother, pregnant women and children were applied. The average consumption rates in the regions of interest, and for the specific groups considered as relatively sensitive to the effects of heavy metals, are presented in Table 29.

#### 4.6.3.1. Fish

Prudente *et al*. (1997) purchased fish samples that are usually for sale from local fishers at the port of Coastal Roads for analysis of metal content

**Table 29. Fish and Shellfish Consumption Rates.**

| Food Group/Subgroup | Consumption Rate | | | | |
|---|---|---|---|---|---|
| | Metro Manila | Central Luzon | Southern Tagalog | | |
| *Fish (g/person/day) | 80 | 69 | 80 | | |
| *Shellfish (g/person/day) | 29.5 | 18 | 16 | | |
| | Age in Years | | | | |
| | All | 14 - 19 | 20 – 29 | 30 – 39 | 40 – 50 |
| **Lactating Women** | | | | | |
| **Fish and Products (g/person/day) | 129 | 181 | 122 | 134 | 113 |
| **Pregnant Women** | | | | | |
| **Fish and Products (g/person/day) | 122 | 90 | 121 | 130 | 102 |
| | Age in Years | | | | |
| **Children** | 1 - < 2 | 2 – < 3 | 3 – 4 | 5 - 6 | |
| **Fish and Products (g/person/day) | 49 | 60 | 65 | 70 | |

**FNRI, 1993*
***FNRI, 1993b*

(Cd, Cu, Pb, Mn, Zn and Hg). The types of fish sampled were demersal and pelagic fish belonging to different species. RQs were calculated for demersal and pelagic fish using average consumption rates in the regions of interest (Table 29). Since only average consumption rates were available, only TDI values for adults were used in computing for RQs. The $RQ_{Geomean}$ was less than one for all heavy metals analyzed with the exception of mercury in pelagic fish for all three regions (Table 30).

$RQ_{Max}$ for Pb exceeded one for demersal and pelagic fish in all areas while $RQ_{Max}$ for Hg is also greater than one but for pelagic animals only (Table 30). A high $RQ_{Max}$ of 6.95 for Hg in pelagic fish was obtained for Metro Manila and Southern Tagalog and 5.99 for Central Luzon.

#### 4.6.3.1.1. Demersal Fish

Both the $RQ_{Geomean}$ and $RQ_{Max}$ were computed for heavy metals in demersal fish using specific consumption rates for groups that are considered to be relatively sensitive to the effects of certain heavy metals (Table 31). The $RQ_{Geomean}$ is greater than one for Pb but only for lactating women of 14 to 19 years old and for children between two to six years old, among the groups considered at risk. It also exceeded one for Hg for lactating women of 14 to 19 years old. On the other hand, $RQ_{Max}$ is greater than one for Zn, Hg and Pb for all the groups of interest and for all age groups with the exception of Hg in children and Zn in a few age groups (11 to 19 and 40 to 50 years old).

$RQ_{Max} > 1$ also for the all-age group for Zn, Hg and Pb for both lactating and pregnant women. Lactating mothers eat about 745 grams of food per day of which 17.3 percent are fish while pregnant women consume about 787 grams/day wherein 15.5 percent are fish. The fish consumption rate of these two groups is almost 1.5 times higher than the fish consumption rate of the average population by region (FNRI-DOST, 1993).

#### 4.6.3.1.2. Pelagic Fish

The results of the RQ analysis for heavy metals in pelagic fish are shown in Table 32. Mercury has $RQ_{Geomean}$ and $RQ_{Max}$ of more than one for lactating women, pregnant women and children (except those one to two years old). Both the $RQ_{Geomean}$ and $RQ_{Max}$ for Pb are greater than one except for lactating women who are 40 to 50 years old and for pregnant women where only the $RQ_{Max}$, but not the $RQ_{Geomean}$, exceeded one. The $RQ_{Max}$ of zinc likewise exceeds one for children one to six years old.

Scad, sardines species and crevalle are among the pelagic fish that appear to have high bioaccumulation of metals with concentration levels in the edible portion (tissue) of 0.067 mg/kg, 1.39 mg/kg and 0.296 mg/kg, respectively. Bioaccumulation means an increase in the concentration of contaminants in a biological organism over time and is the ratio of the concentration in the organism to the concentration in the medium (seawater). Bioaccumulation varies from one organism to the next, and is largely dependent on the feeding habits as well as metabolic and excretory mechanisms of an organism.

**Uncertainty Analysis**

Data presented in the analysis of the relationship of the heavy metals concentration in fish tissues and human health were taken from the study of Prudente, *et al*.. Species included in the study are Slipmouth (*Leiognathus brevirostris*), Ponyfish (*Leiognathus bondus*), Goatfish (*Upenous moluccensis*), Grunt (*Therapon jarbua*), Pomfret (*Apolectus miger*), Mullet (*Valamugil siheli*), Whiting

**Table 30. RQs of Heavy Metals in Demersal and Pelagic Fish Using Average Consumption Rates in Areas around Manila Bay.**

| Metal | MEC | | TDI (µg/person /day) | $RQ_{Geomean}$ | | | $RQ_{Max}$ | | |
|---|---|---|---|---|---|---|---|---|---|
| | Geomean mg/kg | Max mg/kg | mg/ person/day | Metro Manila | Central Luzon | Southern Tagalog | Metro Manila | Central Luzon | Southern Tagalog |
| **Demersal Fish** | | | | | | | | | |
| Cu | 2 | 3.5 | 2000 | 0.08 | 0.07 | 0.08 | 0.14 | 0.12 | 0.14 |
| Zn | 67.5 | 124 | 15000 | 0.36 | 0.31 | 0.36 | 0.66 | 0.57 | 0.66 |
| Cd | 0.016 | 0.071 | 55 | 0.02 | 0.02 | 0.02 | 0.10 | 0.09 | 0.10 |
| Hg | 0.11 | 0.20 | 16 | 0.53 | 0.45 | 0.53 | 0.95 | 0.82 | 0.95 |
| Pb | 0.11 | 0.30 | 15 | 0.60 | 0.51 | 0.60 | 1.61 | 1.39 | 1.61 |
| **Pelagic Fish** | | | | | | | | | |
| Cu | 3.0 | 5.5 | 2000 | 0.12 | 0.10 | 0.12 | 0.22 | 0.19 | 0.22 |
| Zn | 68.3 | 113 | 15000 | 0.36 | 0.31 | 0.36 | 0.60 | 0.52 | 0.60 |
| Cd | 0.014 | 0.067 | 55 | 0.02 | 0.02 | 0.02 | 0.10 | 0.09 | 0.10 |
| Hg | 0.29 | 1.39 | 16 | 1.46 | 1.26 | 1.46 | 6.95 | 5.99 | 6.95 |
| Pb | 0.12 | 0.30 | 15 | 0.66 | 0.56 | 0.66 | 1.58 | 1.36 | 1.58 |

*Source for MECs: Prudente et al., 1997*
*Source for consumption rate: FNRI, 1993*
* Applied age-specific TDIs for Cu (adults), Pb (7yrs-adults), and Zn (adults)

**Table 31. RQs of Heavy Metals in Demersal Fish Tissue for Different Age Groups.**

| Demersal | $RQ_{Geomean}$ | | | | | $RQ_{Max}$ | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Lactating Women** | **Cu** | **Zn** | **Cd** | **Hg** | **Pb** | **Cu** | **Zn** | **Cd** | **Hg** | **Pb** |
| **All age** | 0.13 | 0.58 | 0.04 | 0.85 | 0.96 | 0.22 | 1.07 | 0.18 | 1.64 | 2.59 |
| 14-19 | 0.18 | 0.82 | 0.05 | 1.19 | 1.35 | 0.31 | 1.50 | 0.23 | 2.31 | 3.63 |
| 20-29 | 0.12 | 0.55 | 0.04 | 0.80 | 0.91 | 0.21 | 1.01 | 0.16 | 1.56 | 2.45 |
| 30-39 | 0.14 | 0.60 | 0.04 | 0.88 | 1.00 | 0.23 | 1.11 | 0.17 | 1.71 | 2.69 |
| 40-50 | 0.11 | 0.51 | 0.03 | 0.74 | 0.84 | 0.20 | 0.93 | 0.15 | 1.44 | 2.27 |
| **Pregnant Women** | | | | | | | | | | |
| **All age** | 0.12 | 0.55 | 0.04 | 0.80 | 0.54 | 0.21 | 1.01 | 0.16 | 1.56 | 1.47 |
| 14-19 | 0.09 | 0.41 | 0.03 | 0.59 | 0.40 | 0.16 | 0.74 | 0.12 | 1.15 | 1.08 |
| 20-29 | 0.12 | 0.54 | 0.04 | 0.80 | 0.54 | 0.21 | 1.00 | 0.16 | 1.54 | 1.46 |
| 30-39 | 0.13 | 0.59 | 0.04 | 0.85 | 0.58 | 0.22 | 1.08 | 0.17 | 1.66 | 1.57 |
| 40-50 | 0.10 | 0.46 | 0.03 | 0.67 | 0.46 | 0.18 | 0.84 | 0.13 | 1.30 | 1.23 |
| **Children** | | | | | | | | | | |
| 1-2 | 0.25 | 0.66 | 0.01 | 0.32 | 0.91 | 0.42 | 1.22 | 0.06 | 0.62 | 2.46 |
| 2-3 | 0.30 | 0.81 | 0.02 | 0.39 | 1.12 | 0.52 | 1.49 | 0.08 | 0.77 | 3.01 |
| 3-4 | 0.33 | 0.88 | 0.02 | 0.43 | 1.21 | 0.56 | 1.61 | 0.08 | 0.83 | 3.26 |
| 4-6 | 0.35 | 0.95 | 0.02 | 0.46 | 1.30 | 0.61 | 1.74 | 0.09 | 0.89 | 3.51 |
| **$MEC_{Geomean}$ and $MEC_{Max}$ (ng/g)** | 201 8 | 67.5 x $10^3$ | 16.3 | 105 | 111.9 | 3460 | 124.0 x $10^3$ | 71.0 | 204 | 301.0 |
| **TDIs* (µg/person /day)** | 400; 200 0 | 5000; 15000 | 55 | 16 | 6; 15; 25 | 400; 2000 | 5000; 15000 | 55 | 16 | 6; 15; 25 |

*Source for MECs: Prudente et al., 1997*
*Source for consumption rate: FNRI, 1993b*
** Applied age-specific TDIs as appropriate: Cu (1-10 yrs. & adults); Pb (0-6 yrs; 7-adults & pregnant women); Zn (1-10 yrs. & adults)*

**Table 32. RQs of Heavy Metals in Pelagic Fish Tissue for Different Age Groups.**

| Pelagic | $RQ_{Geomean}$ | | | | | $RQ_{Max}$ | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Lactating Mother | Cu | Zn | Cd | Hg | Pb | Cu | Zn | Cd | Hg | Pb |
| All age | 0.19 | 0.59 | 0.03 | 2.35 | 1.06 | 0.35 | 0.97 | 0.16 | 11.21 | 2.55 |
| 14-19 | 0.27 | 0.82 | 0.05 | 3.30 | 1.48 | 0.49 | 1.36 | 0.22 | 15.72 | 3.57 |
| 20-29 | 0.18 | 0.56 | 0.03 | 2.22 | 1.00 | 0.33 | 0.92 | 0.15 | 10.60 | 2.41 |
| 30-39 | 0.20 | 0.61 | 0.03 | 2.44 | 1.10 | 0.37 | 1.01 | 0.16 | 11.64 | 2.64 |
| 40-50 | 0.17 | 0.51 | 0.03 | 2.06 | 0.93 | 0.31 | 0.85 | 0.14 | 9.82 | 2.23 |
| Pregnant Women | | | | | | | | | | |
| All-age group | 0.18 | 0.56 | 0.03 | 2.22 | 0.60 | 0.33 | 0.92 | 0.15 | 10.60 | 1.44 |
| 14-19 | 0.14 | 0.41 | 0.02 | 1.64 | 0.44 | 0.25 | 0.68 | 0.11 | 7.82 | 1.07 |
| 20-29 | 0.18 | 0.55 | 0.03 | 2.20 | 0.59 | 0.33 | 0.91 | 0.15 | 10.51 | 1.43 |
| 30-39 | 0.20 | 0.59 | 0.03 | 2.37 | 0.64 | 0.35 | 0.98 | 0.16 | 11.29 | 1.54 |
| 40-50 | 0.15 | 0.46 | 0.03 | 1.86 | 0.50 | 0.28 | 0.77 | 0.12 | 8.86 | 1.21 |
| Children | | | | | | | | | | |
| 1-2 | 0.37 | 0.67 | 0.01 | 0.89 | 1.00 | 0.67 | 1.11 | 0.06 | 4.26 | 2.42 |
| 2-3 | 0.45 | 0.82 | 0.02 | 1.09 | 1.23 | 0.82 | 1.36 | 0.07 | 5.21 | 2.96 |
| 3-4 | 0.49 | 0.89 | 0.02 | 1.18 | 1.33 | 0.89 | 1.47 | 0.08 | 5.65 | 3.21 |
| 4-6 | 0.53 | 0.96 | 0.02 | 1.28 | 1.43 | 0.95 | 1.58 | 0.09 | 6.08 | 3.45 |
| $MEC_{Geomean}$ and $MEC_{Max}$ (ng/g) | 3013 | 68.3 x $10^3$ | 14.2 | 291 | 122.8 | 5450 | 113 x $10^3$ | 67.4 | 1390 | 296.0 |
| TDIs* (µg/person /day) | 400; 2000 | 5000; 15000 | 55 | 16 | 6; 15; 25 | 400; 2000 | 5000; 15000 | 55 | 16 | 6; 15; 25 |

*Source for MECs: Prudente et al., 1997*
*Source for consumption rate: FNRI, 1993b*
** Applied age-specific TDIs as appropriate: Cu (1-10 yrs. & adults); Pb (0-6 yrs; 7-adults & pregnant women); Zn (1-10 yrs. & adults)*

(*Sillago sihama*), Snapper (*Lutjamus russeli*), and Siganid (*Lutjamus russeli*) representing those found in the demersal habitat. Those found in the pelagic area were represented by Scad (*Decapterus macrosoma*), Sardine (*Sardinella leiogaster*), Crevalle (*Selaroides leptolepis*), Sardine sp. (*Sardinella punctatus*), Hairtail (Trichmurus lepterus), Perch (*Anabas testudinaus*), Mackerel (*Scomberomorous commerson*), and Leather jacket (*Scomberoides sp.*). Data presented in this report include the results of the site-specific, age-specific food consumption survey conducted in Metro Manila, Central Luzon and Southern Tagalog Regions with emphasis on lactating women, pregnant women, and children from one to six years old. For the lactating and the pregnant women, the study focused on all age groups, i.e., 14 to 19 year-old group, 20 to 29 year-old group, 30 to 39 year-old group and the 40 to 50 year-old group.

Data which gave RQs very close to one were subjected to Uncertainty Analysis using Monte Carlo Simulation as programmed in Crystal Ball 4.0g software. Table 33 summarizes the results of the Uncertainty Analysis on heavy metals in fish tissue in relation to the different groups surveyed. Based on the analysis, the probability that the RQ for Pb would exceed one is highest among the heavy metals. Pb is detected in the edible portion of most of the demersal species, e.g., in whiting and siganid samples, with concentrations ranging from 37.5 to 301 ng/g dry weight of fish tissue. Monte Carlo Simulation results indicated that the

**Table 33. Summary of the Results of Uncertainty Analysis on Heavy Metals in Fish Tissues in Relation to Different Groups Surveyed.**

| Surveyed Group | Age Group | Heavy Metal | Habitat | Species | RQ | $RQ_{Geomean}$ (Species Grouping) | Certainty Level (%) |
|---|---|---|---|---|---|---|---|
| **Lactating Women** | All | Pb | Demersal | Whiting (*Sillago sihama*) | 0.912 | 0.962 | 34.10 |
| | 14-19 | Hg | Demersal | Grunt (*Therapon jarbua*) | 0.982 | 1.093 | 50.00 |
| | 20-29 | Pb | Demersal | Siganid (Siganidae) | 1.090 | 0.907 | 30.90 |
| | 30-39 | Pb | Demersal | Whiting (*Sillago sihama*) | 0.947 | 0.997 | 39.40 |
| | 40-50 | Pb | Pelagic | Mackerel (*Scomberomorous commerson*) | 0.979 | 0.925 | 33.60 |
| **Children** | 1-2 | Pb | Demersal | Siganid (Siganidae) | 1.094 | 0.911 | 33.90 |
| | | Pb | Pelagic | Mackerel (*Scomberomorous commerson*) | 1.062 | 0.925 | 38.90 |
| | 2-3 | Pb | Demersal | Whiting (*Sillago sihama*) | 1.060 | 1.116 | 50.50 |
| | 4-6 | Zn | Pelagic | Mackerel (*Scomberomorous commerson*) | 0.973 | 0.956 | 35.80 |

probability that the RQ for Pb in fish tissue will exceed one is 30.90 percent to 50.50 percent. The RQ for Hg concentration was also found to exceed one with a probability of 50.0 percent while the RQ for Zn found in pelagic fishes will exceed one with a probability of 35.8 percent.

Uncertainty Analysis of Pb concentrations in fish tissues from demersal habitat indicated that the heavy metal may affect all of the surveyed groups except for the 14 to 19 year-old age bracket for lactating women and four to six year old age bracket for children.

#### 4.6.3.2. Shellfish

The contents of Cd, Cu, Pb and Zn in shellfish samples (mussels and oysters) from Manila Bay from the mouth of the Pasig River were also investigated. High RQ values of 3.8 to 7 were obtained for Pb in the regions of interest suggesting that Pb in shellfish may pose a relatively significant risk to human health.

In the calculation of $RQ_{Geomean}$ and $RQ_{Max}$, site-specific shellfish consumption rates for Metro Manila, Central Luzon and Southern Tagalog were used (Table 29). As explained previously, these areas are proximal to Manila Bay and accordingly are presumed to obtain their seafood requirements mainly from Manila Bay. In the FNRI-DOST study (FNRI-DOST, 1993), it was assumed that adults and children of both sexes consumed food at equal rates. Thus, the values of 29.5, 18, and 16 grams/person/day will be applied to Metro Manila, Central Luzon and Southern Tagalog, respectively, in calculating RQs. Since the consumption rates applied for each region are not age-specific, application of age-specific TDIs for various age groups in order to get separate RQs was not carried out since this may over-estimate the risk for the younger age groups (low consumption group). RQs were instead obtained using only the TDIs for adults.

Table 34 shows that all the metals, with the exception of Cd which has an $RQ_{Max}$ of less than

**Table 34. RQs of Heavy Metals in Shellfish Tissue.**

| Metal | $MEC_{Gm}$ mg/kg dw | $MEC_{Max}$ mg/kg dw | TDI µg/person/ day | $RQ_{Geomean}$ | | | $RQ_{Max}$ | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Metro Manila | Central Luzon | Southern Tagalog | Metro Manila | Central Luzon | Southern Tagalog |
| Cadmium | 0.22 | 2.20 | 55 | 0.12 | 0.07 | 0.06 | 1.18 | 0.72 | 0.64 |
| Copper | 35.82 | 187 | 2000 | 0.53 | 0.32 | 0.29 | 2.76 | 1.68 | 1.50 |
| Lead | 0.18 | 3.60 | 15 | 0.35 | 0.21 | 0.19 | 7.08 | 4.32 | 3.84 |
| Mercury | 0.001 | 2.70 | 16 | 0.003 | 0.002 | 0.001 | 4.98 | 3.04 | 2.70 |
| Zinc | 282.56 | 1590 | 15000 | 0.56 | 0.34 | 0.30 | 3.13 | 1.91 | 1.70 |

*Source for MECs: PRRP, 1999*
*Source for consumption rate: FNRI, 1993*
*Source for TDIs: U.S. FDA, 2001 (Selected age-specific TDIs: Cu for adults; Pb for 7 yrs-adults; and Zn for adults)*

**Table 35. RQs of Heavy Metals in Shellfish (Bivalves) Tissue.**

| Metal | MECGm mg/kg dw | MECMax mg/kg dw | TDI µg/person/ day | $RQ_{Geomean}$ | | | $RQ_{Max}$ | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Metro Manila | Central Luzon | Southern Tagalog | Metro Manila | Central Luzon | Southern Tagalog |
| Cadmium | 0.05 | 0.18 | 55 | 0.03 | 0.02 | 0.01 | 0.10 | 0.06 | 0.05 |
| Copper | 4.31 | 7.05 | 2000 | 0.06 | 0.04 | 0.03 | 0.10 | 0.06 | 0.06 |
| Lead | 0.68 | 1.32 | 15 | 1.34 | 0.82 | 0.73 | 2.59 | 1.58 | 1.41 |
| Chromium | 0.52 | 2.97 | 200 | 0.08 | 0.05 | 0.04 | 0.44 | 0.27 | 0.24 |

*Source for MECs: BFAR, 1995.*
*Source for consumption rates: FNRI, 1993*
*Source for TDIs: U.S. FDA, 2001 (Selected age-specific TDIs: Cu for adults; Pb for 7 yrs-adults; and Zn for adults)*

one in Central Luzon and Southern Tagalog, have $RQ_{Max}$ greater than one. The $RQ_{Geomean}$ for all other metals however, were less than one in the regions of interest. For Cu and Zn, which are essential metals, less importance is attached to RQ values greater than one but an RQ greater than 10 may be a cause for concern.

With regard to the RQs of heavy metals in bivalves (FSP-REA/BFAR, 1993), only TDIs for adults were used in computing for RQs since the consumption rates used were not age-specific. Table 35 shows that Pb is the only metal with RQs exceeding one. Lead concentration levels are highest in bivalve samples taken during the rainy season (August) from Bataan (1.32 mg/kg) and Pampanga (1.13 mg/kg). The $RQ_{Geomean}$ for Pb exceeded one only in Metro Manila while the $RQ_{Max}$ for Pb for all the three regions of interest exceeded one.

### 4.6.4. Sources of Heavy Metals

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 operations and metallurgical activities) to sea-based sources (port and maritime activities).

Although the heavy metal concentrations in water inside the bay are a low cause for concern, the higher concentrations in the river mouths suggest that land-based activities along the rivers are contributing significantly to heavy metal load in Manila Bay.

The heavy metal load in the bay is better manifested in the high concentrations in sediment. 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 can bio-accumulate in varying degrees in the organism through ingestion. Some metals are essential to organisms, some are metabolized and excreted or retained in tissues in less harmful forms, while others are non-essential. However, even the essential metals, when uptake or ingestion rate is faster than the rate that these can be processed, could bio-concentrate and become harmful to the health of the organism. The accumulated metals, particularly those that undergo bio-magnification, could also pose potential risks to human health mainly through consumption of contaminated seafood. The effects of heavy metals to human health and relative risks among these metals in terms of toxicity and bioaccumulation are discussed at length in Section 5.4 (Comparative Risk Assessment).

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

## 4.7. PESTICIDES

### 4.7.1. Water Column

Data on pesticides are limited to the analysis of 16 organochlorine pesticide species samples from five surface water stations in Manila Bay by the PRRP in 1996. These pesticides are the following: aldrin, alpha-BHC, beta-BHC, delta-BHC, gamma-BHC, 4.4'-DDD, 4.4'-DDE, 4.4'-DDT, dieldrin, endosulfan I, endosulfan II, endosulfan sulphate, endrin, heptachlor, heptachlor epoxide, and methoxychlor. For 15 substances, all concentrations were found to be below the detection limit. Only for heptachlor were values found to be above the detection limit, i.e., in the range of 0.066-0.282 μg/L for 5 stations. Using the marine chronic criteria from the US EPA of 0.0035 μg/L as PNEC, the calculated minimum RQ was 18.86 while the maximum RQ was 80.57 for heptachlor. The minimum RQ exceeding one indicates significant risk from heptachlor in Manila Bay waters.

### 4.7.2 Sediment

The data were derived from the PRRP Report (PRRP, 1999) and the study by Bajet *et al.* (1998). Concentrations of 16 organochlorine pesticides (aldrin, alpha-BHC, beta-BHC, delta-BHC, gamma-BHC, 4.4'-DDD, 4.4'-DDE, 4.4'-DDT, dieldrin, endosulfan I, endosulfan II, endosulfan sulphate, endrin, heptachlor, heptachlor epoxide, and methoxychlor) were measured in sediment from 10 established PRRP monitoring stations in March 1996 and September/October 1996. The PNECs used, available only for 4.4'-DDE and 4.4'-DDT, were from the HK ISQV (EVS, 1996).

All the values observed were less than the detection limits. All MECs for 4.4'-DDE were < 0.004 mg/kg dry weight (dw) while all MECs for 4.4'-DDT were < 0.010 mg/kg dw. For computation purposes, 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 calculated RQs were 1.8 for 4.4'-DDE and 5.7 for 4.4'-DDT, but because of the large uncertainty in MECs at or near detection limits, these RQs need to be verified with additional data. It should also be noted that the detection limits for these pesticides are actually higher than the criteria from the HK ISQV (2.2 μg/kg for 4.4'-DDE and 1.58 μg/kg for 4.4'-DDT).

Calculation of RQ was also made for aldrin (MECs < 0.002 mg/dry kg), dieldrin (MECs < 0.004 mg/dry kg) and heptachlor (MECs < 0.002 mg/dry kg) using the US EPA 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 according to Van der Kooij et al. (1991). The RQ values for these three pesticides were all less than one.

The study by Bajet et al. (1998) measured organochlorine pesticides in sediment collected from the mouth of rivers draining to Manila Bay. Box 1 shows the pesticides that were detected.

**Box 1. Pesticide Detection.**

**Detected in decreasing order of frequency during the end of the rainy season (December 1996)**

| Pesticide | $MEC_{Min}$, ng/g | $MEC_{Max}$, ng/g | PNEC, ppm | $RQ_{Max}$ |
|---|---|---|---|---|
| | | | | |
| DDE | 0.3 | 8.9 | None | - |
| DDT | <0.5 | 0.8 | 5 | 0.0002 |
| Dieldrin | <0.2 | 1.4 | 0.5 | 0.003 |
| Aldrin | - | <0.4 | 0.1 | <0.004 |
| Lindane | <0.4 | 1.3 | None | - |

DDE (MECMin = 0.1 ng/g and MECMax = 0.4) was the only pesticide detected in June 1997.

There is no PNEC for DDE.

**Detected in decreasing order during the middle of the rainy season (September 1997)**

| Pesticide | $MEC_{Min}$, ng/g | $MEC_{Max}$, ng/g | PNEC, ppm | $RQ_{Max}$ |
|---|---|---|---|---|
| Aldrin | <0.4 | 11.3 | 0.1 | 0.113 |
| | | | | |
| DDE | <0.4 | 18.4 | None | - |
| HCB | <0.2 | 2.2 | None | - |
| DDD | <0.4 | 14.4 | None | - |
| Lindane | <0.4 | 6.4 | None | - |
| Dieldrin | <0.2 | 0.5 | 0.3 | 0.002 |

**Detected in decreasing order of frequency during the end of the rainy season (January 1998).**

| Pesticide | $MEC_{Min}$, ng/g | $MEC_{Max}$, ng/g | PNEC, ppm | $RQ_{Max}$ |
|---|---|---|---|---|
| Aldrin | <0.4 | 2.1 | 0.1 | 0.021 |
| HCB | <0.2 | 1.2 | None | - |
| DDD | <0.4 | 8.9 | None | - |
| | | | | |
| Lindane | <0.4 | 0.6 | None | - |

**Detected during the dry season.**

| Pesticide | $MEC_{Min}$, ng/g | $MEC_{Max}$, ng/g | PNEC, ppm | $RQ_{Max}$ |
|---|---|---|---|---|
| Aldrin | <0.4 | 3.6 | 0.1 | 0.036 |
| DDE | <0.4 | 2.1 | None | - |
| Endosulfan | <0.2 | 2.1 | None | |
| HCB | <0.2 | 0.3 | None | - |
| Lindane | <0.4 | 2.1 | None | - |

The data shows the persistence of some organochlorines in the sediments despite their restricted status. For instance, DDT has already been banned for agricultural and health uses; endosulfan is currently restricted for institutional use only; aldrin was registered for termite control but is currently not marketed in the country; and lindane is not widely used. Be that as it may, these pesticides continue to be detected ($MEC_{Max}$)

It should be noted that the RQs for pesticides in sediments are in general below the critical RQ level.

### 4.7.3. Tissue

The levels of 16 common pesticides (aldrin, alpha-BHC, beta-BHC, delta-BHC, gamma-BHC, 4.4'-DD, 4.4'-DDE, 4.4'-DDT, dieldrin, heptachlor, methoxychlor, endosulfan I, endosulfan II, endosulfan sulfate and endrin) were measured in shellfish taken from five stations of the Bay in 1996 (PRRP, 1999). The five stations are located in Malolos, Bulacan; and in Kawit and Bacoor which are both in the province of Cavite. These areas are being used for the commercial growing of oysters or mussels or both. TDI values were available only for aldrin, 4.4'-DDE, 4.4'-DDT, dieldrin, endosulfan 1, endosulfan II, endosulfan sulfate and endrin. To determine the risks of these substances, RQs were calculated using shellfish consumption rate of 29.5, 18, and 16 grams/person/day for Metro Manila, Central Luzon and Southern Luzon (FNRI, 1993), respectively. For shellfish consumption rates, there are no specific values for lactating women, pregnant women and children. With the exception of endosulfan sulfate, endosulfan I and endrin, RQs were less than one for all pesticides analyzed. The high $RQ_{Max}$ values (RQ>1) can be found at stations in Malolos, Bulacan and Bacoor, Cavite. The $RQ_{Geomean}$ for all the pesticides examined are less than one. The results of the risk analysis in terms of RQs are shown in Table 36.

Concentrations of aldrin, alpha-BHC and heptachlor in fish were also cited in Tuazon and Ancheta (1992). The reported concentrations were 1.20 mg/kg, 4.11 mg/kg, and 3.25 mg/kg , respectively. 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

**Table 36. RQ of Pesticides in Shellfish Tissue.**

| Pesticides | $MEC_{Gm}$ µg/g dry | $MEC_{Max}$ µg/g dry | TDI in µg/person/ day | $RQ_{Geomean}$ | | | $RQ_{Max}$ | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Metro Manila | Central Luzon | Southern Tagalog | Metro Manila | Central Luzon | Southern Tagalog |
| Aldrin | 0.014 | 0.141 | 4.8 | 0.09 | 0.05 | 0.05 | 0.87 | 0.53 | 0.47 |
| 4.4'-DDE | 0.019 | 0.019 | 80 | 0.01 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 |
| 4.4'ddt | 0.080 | 0.129 | 80 | 0.03 | 0.02 | 0.02 | 0.05 | 0.03 | 0.03 |
| Dieldrin | 0.019 | 0.019 | 4.8 | 0.12 | 0.07 | 0.06 | 0.12 | 0.07 | 0.06 |
| Endosulfan I | 0.036 | 0.178 | 4.8 | 0.22 | 0.14 | 0.12 | 1.09 | 0.67 | 0.59 |
| Endosulfan II | 0.025 | 0.068 | 4.8 | 0.16 | 0.10 | 0.08 | 0.42 | 0.26 | 0.23 |
| Endosulfan Sulphate | 0.094 | 0.306 | 4.8 | 0.58 | 0.35 | 0.31 | 1.88 | 1.15 | 1.02 |
| Endrin | 0.072 | 0.220 | 4.8 | 0.44 | 0.27 | 0.24 | 1.35 | 0.83 | 0.73 |
| Heptachlor | 0.020 | 0.057 | 4.8 | 0.13 | 0.08 | 0.07 | 0.35 | 0.21 | 0.19 |

*Source of MECs: PRRP, 1999*
*Source of PNECs: FNRI-DOST, 1993*

heptachlor were obtained. There was no TDI available for alpha-BHC so the RQ for this pesticide 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 MECs used were, however, individual values, which were cited without proper documentation or explanation (data quality score is three) such that the RQs are associated with large uncertainties and need to be verified.

The major possible source of pesticides in the bay is run-off 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 might be alarming at present, the results of the risk assessment signal cause for concern, particularly for the endosulfans in shellfish, and aldrin and heptachlor in fish. It should also be borne in mind that pesticides can be persistent and cumulative, such that chronic effects may become apparent over time.

**Uncertainty Analysis**

There were very limited data for pesticides in water but the RQs obtained from the few data available suggest that this parameter should be examined more closely using additional data. For sediment 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 sediment, all the data for which threshold values were available were reported as less than the detection limit (<0.004 mg/kg dry weight for 4.4'-DDE and <0.010 mg/kg dry weight 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 dry weight and 0.009 mg/kg dry weight. The average RQs obtained for these pesticides in sediment were greater than one. It is, however, uncertain if these RQs are really indicative of risks from these pesticides or are artifactual due to 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 sediment were estimated using partition coefficients. The RQs obtained for these pesticides were all less than one although the suitability of the estimated critical sediment concentrations for use as PNECs should still be verified.

Data on organochlorine pesticides in water has been assigned a score of two for data quality, i.e., some quality assurance/quality control-related documentation has not been included in the PRRP report for these parameters.

The data generated by Bajet et al. (1998) has been assigned a score of two for data quality. Despite this, the data values are included in the refined risk assessment in the absence of any other data sets.

Not all of the pesticides being analyzed have TDI values available. The toxic dose for each pesticide should also be made available to determine if the amount of pesticides taken by man through food (shellfish) ingestion is still within the limit.

Pesticides included in the study were evaluated and computed for their RQ. Of all of the pesticides studied, only endosulfan sulfate in shellfish has an $RQ_{Max}$ value that exceeded one. Monte Carlo Simulation for the said pesticide resulted in certainty level of 93.80 percent that its RQ will exceed one. Uncertainty analysis was not conducted for aldrin and heptachlor in fish because the RQs were comparatively high and were computed from individual MEC values.

The data quality score of the data on pesticides in fish tissue (Tuazon and Ancheta, 1992) is in fact three since the values were cited without proper documentation and explanation.

Additional data for pesticides in water and tissue in the other areas of the bay should therefore be gathered especially near Pampanga River where there are extensive agricultural activities. The establishment of PNECs and TDIs are also 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.

## 4.8. NUTRIENTS

The term "nutrients" in this report refers to nitrate, ammonia, and phosphate. Nitrate levels have been reported in terms of nitrate-nitrogen; ammonia as ammonia-nitrogen, and phosphate as phosphate-phosphorus. Nutrients are constituents of domestic, commercial or institutional liquid wastes, untreated or partially treated industrial effluents, solid waste leachate, and agricultural runoff.

The average and maximum RQs for the nutrients are given in Table 37.

All the values for the worst-case RQs for nutrients are greater than one. The $RQ_{Geomean}$ values, however, are < 1 for nitrate and ammonia and > 1 for phosphate.

### 4.8.1. Nitrate-Nitrogen

The data for nitrate in the water column were taken from the PRRP Report (PRRP,1999). The data used was obtained monthly from 1996-1998 from eight stations spread across the Bay. The criteria value (i.e., 60 μg/L) used was from the ASEAN Marine Water Quality Criteria (ASEAN, 2003).

Figure 33 shows the scatter plot distribution of nitrate at the different sampling depths for the period 1996-1998. The maximum values ($MEC_{Max}$) appeared to be outliers.

Table 38 shows the $RQ_{Geomean}$ ranges for nitrate at different sampling depths for the period 1996-1998.

The levels of $RQ_{Geomean}$ for nitrate at the surface of Manila Bay from 1996 to 1998 did not show marked variation, with all RQs less than one (Table 38). RQs for nitrate at mid-depth are relatively higher than those at the surface, but are still less than one and pose low risk. Nitrate RQs at the bottom, however, portray a different situation as hot spots were noted in 1996 and 1997. Surfer plots were generated to look at the distribution of RQs in the eight stations and at different seasons for bottom waters.

**Table 37. RQs of Nutrients in Manila Bay.**

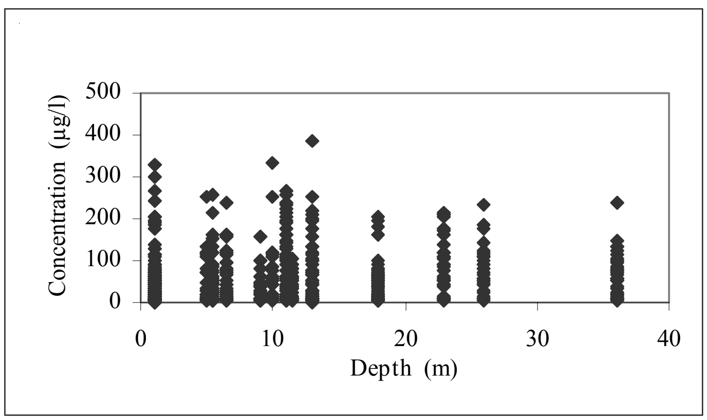
| Agent | $MEC_{Geomean}$ (mg/L) | $MEC_{Max}$ (mg/L) | PNEC (mg/L) | $RQ_{Geomean}$ | $RQ_{Max}$ |
|---|---|---|---|---|---|
| Nitrate | 0.027 (n=769) | 0.387 | 0.06 | 0.40 | 6 |
| Ammonia | 0.003 (n=769) | 0.779 | 0.07 | 0.04 | 11 |
| Phosphate | 0.029 (n=558) | 0.714 | 0.015 | 1.93 | 47.60 |

*Source of MEC: PRRP, 1999.*
*Source of PNECs: ASEAN, 2003.*

As shown in Figure 34, only one station (near the mouth of Bulacan River) out of the eight stations monitored exhibited RQ < 1 during the wet season of 1996. All other stations had RQs > 1. During the dry season of 1996-1997, the situation slightly improved: five stations had RQs > 1 while the remaining three had RQs < 1. Hot spots were located in the eastern and central portions of the Bay. The situation again deteriorated during the wet season of 1997 when practically all stations (except for one station) again exhibited RQs >1. During the dry season of 1997-1998, Manila Bay's bottom waters significantly improved in terms of nitrate. All stations exhibited RQs < 1.

Figure 34 illustrates the influence of seasonal variations on nitrate concentrations of bottom waters. Manila Bay waters showed improved nitrate levels during the dry season. Water quality in terms of nitrate, however, worsened during the wet season. This could be attributed to increased land-based inputs of runoff, domestic sewage, and agricultural residuals. As shown by the classed post maps, there has been an improvement in the Manila Bay bottom water quality in terms of nitrate in 1998 when compared to 1996.

**Figure 33. Scatter Plot of Data for Nitrate.**



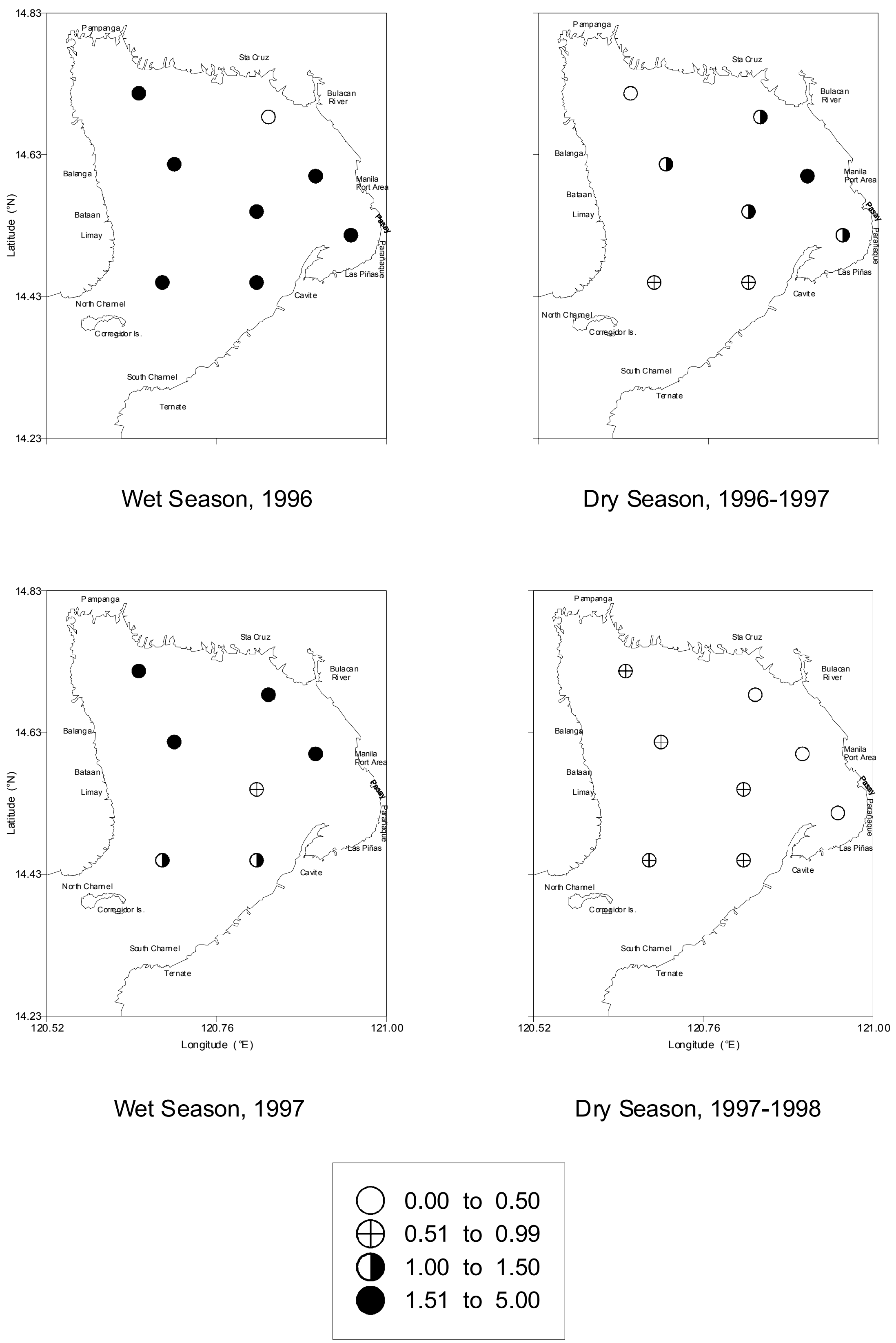

*Source: PRRP, 1999.*

**Table 38. $RQ_{Geomean}$ Ranges for Nitrate.**

| Year | $RQ_{Geomean}$ Range | | |
|---|---|---|---|
| | Surface | Mid-depth | Bottom |
| 1996 | 0.17-0.46 (n=77) | 0.32-0.49 (n=73) | 0.38-1.63 (n=77) |
| 1997 | 0.35-0.59 (n=88) | 0.40-0.80 (n=88) | 0.74-1.04 (n=87) |
| 1998 | 0.19-0.34 (n=93) | 0.25-0.35 (n=93) | 0.28-0.56 (n=93) |

*Source of MEC: PRRP, 1999.*
*Source of PNECs : ASEAN, 2003.*

**Figure 34. RQs for Nitrates in Bottom Waters of Manila Bay Showing Seasonal Effects.**



### 4.8.2. Ammonia-Nitrogen

The data for ammonia in the water column were taken from the PRRP Report (1999). The data used were obtained monthly from eight stations spread across the bay during the period from 1996-1998. The criteria value (i.e., 70 µg/L) used was from the ASEAN Marine Water Quality Criteria (ASEAN, 2003).

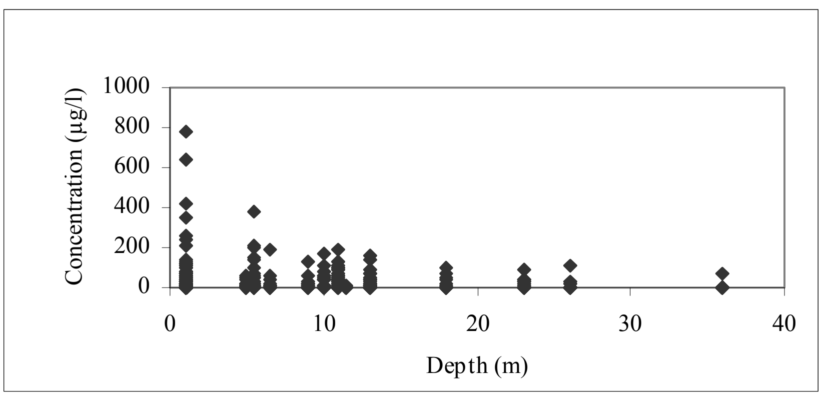
Figure 35 shows the scatter plot distribution of ammonia at the different sampling depths for the period 1996-1998. As with nitrate, the maximum values ($MEC_{Max}$) appeared to be outliers.

Table 39 shows the RQ ranges for ammonia at different sampling depths for the period 1996-1998.

All RQs for ammonia at all depths in Manila Bay for the period 1996-1998 were below one. It is worth noting, however, that the highest RQs were consistently observed at the station nearest the discharge area of Pasig River. Over the three-year period, the water quality of Manila Bay in terms of ammonia has improved.

All the values for the worst-case RQs for nutrients are greater than one as shown in Table 37. The $RQ_{Geomean}$ for ammonia, however, was less than one. The environmental concentrations of ammonia were below the critical level and therefore do not appear to be problematic. In general, concentrations during the dry season were somewhat lower than during the wet season.

**Figure 35. Scatter Plot of Data for Ammonia.**




*Source: PRRP, 1999.*

### 4.8.3. Phosphate-Phosphorus

The data for phosphate in the water column were taken from the PRRP Report (PRRP, 1999). The data used were obtained monthly from eight stations spread across the Bay during the period 1996-1998. The criteria value (i.e., 15 µg/L for coastal waters) used was from the ASEAN Marine Water Quality Criteria (ASEAN, 2003).

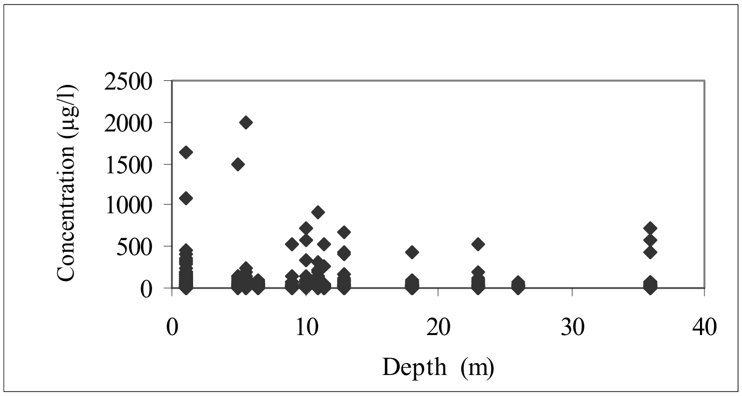
Figure 36 shows the scatter plot distribution of phosphate at the different sampling depths for the period 1996-1998. As with nitrate and ammonia, the maximum values ($MEC_{Max}$) appeared to be outliers but analysis of data revealed that the higher MEC values were not dissolved inorganic phosphate but particulate phosphate.

**Table 39. $RQ_{Geomean}$ Ranges for Ammonia.**

| Year | $RQ_{Geomean}$ Range | | |
|---|---|---|---|
| | Surface | Mid-depth | Bottom |
| 1996 | 0.02-0.16 (n=77) | 0.02-0.03 (n=73) | 0.02-0.15 (n=77) |
| 1997 | 0.03-0.18 (n=88) | 0.02-0.10 (n=88) | 0.01-0.17 (n=87) |
| 1998 | 0.02-0.09 (n=93) | 0.02-0.05 (n=93) | 0.01-0.05 (n=93) |

*Source of MEC: PRRP, 1999.*
*Source of PNECs : ASEAN, 2003.*

**Figure 36. Scatter Plot of Data for Phosphate.**




*Source: PRRP, 1999*

Table 40 shows the $RQ_{Geomean}$ ranges for phosphate at different sampling depths for the period 1996-1998. $RQ_{Geomean}$ exceeded one in most cases at surface, mid-depth and bottom layers of the water column. All the $RQ_{Geomean}$ calculated based on 1998 data were greater than one at all depths studied, indicating that the phosphate levels have deteriorated further than previous years covered by the study.

Figure 37 presents the extent of critical RQ levels for phosphate in the surface water of the Bay through a series of contour maps. During the dry season of 1996-1997 and the wet season of 1997 RQs > 1 covered the eastern portion of the Bay. The highest phosphate levels were found near Manila. During the dry season of 1997-1998 the area covered by RQs >1 appear to have widened and the highest levels shifted toward the Bay's center. Manila Bay's surface water quality in terms of phosphate deteriorated over the three-year period.

Figure 38 shows the distribution of $RQ_{Geomean}$ levels at the bottom waters of the Bay. During the dry season of 1996-1997 all areas covered by the sampling stations had RQ > 1. The highest RQ levels are found in areas near Cavite, Paranaque, Metro Manila, and Bulacan. During the wet season of 1997 and the dry season of 1997-1998, all RQ levels were again above one. The highest RQs were found in the vicinity of Port Area, Manila.

The bottom water quality in the bay in terms of phosphate deteriorated over the two-year sampling period. This is manifested by the worst case RQ of 47.6 and $RQ_{Geomean}$ of 1.93 (n = 558). Of the three nutrients, phosphate is considered as a significant environmental stressor in Manila Bay. Phosphate is traceable to contributions from agricultural residuals, domestic sewage, and detergents.

**Uncertainty Analysis**

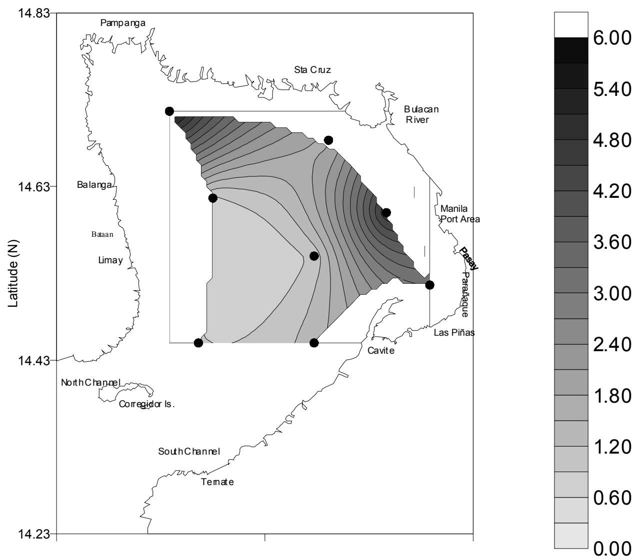
For nitrate, the highest certainty levels that the $RQ_{Geomean}$ exceeded one (certainty level = 10.90-28.60 percent, S.D. range: 0.56-0.97) are found in data sets for nitrate at the bottom stations for the period 1996 and 1997. These findings are consistent with the contour plots

**Table 40. $RQ_{Geomean}$ Ranges for Phosphate.**

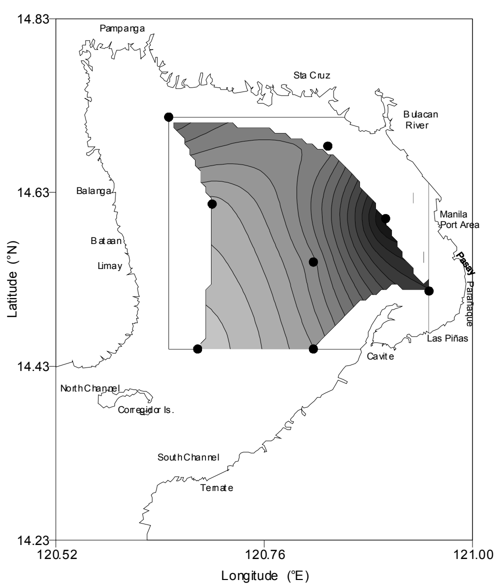
| Year | $RQ_{Geomean}$ Range | | |
|---|---|---|---|
| | Surface | Mid-depth | Bottom |
| 1996* | 0.93-3.24 (n=77) | 0.020-0.032 (n=73) | 0.02-0.15 (n=77) |
| 1997 | 0.98-3.50 (n=88) | 1.08-2.75 (n=88) | 1.65-3.17 (n=87) |
| 1998 | 1.48-3.14 (n=93) | 1.13-2.63 (n=93) | 1.40-3.73 (n=93) |

*Legend: * = Particulate Phosphate concentrations were measured*
*Source of MEC: PRRP, 1999.*
*Source of PNECs : ASEAN, 2003.*

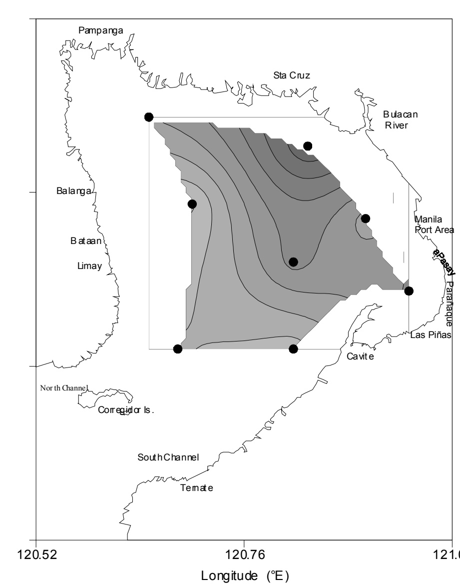
**Figure 37. RQs for Phosphate in Surface Waters of Manila Bay and Seasonal Variations.**




Dry Season, 1996-1997

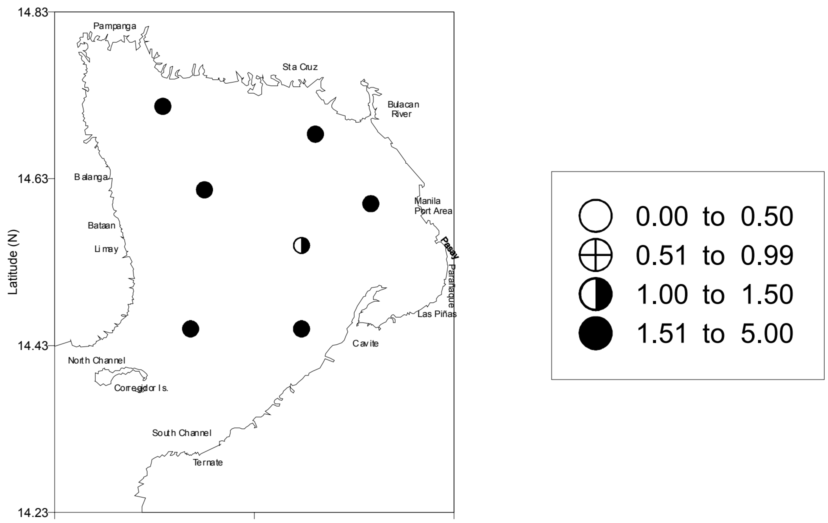



Wet Season, 1997

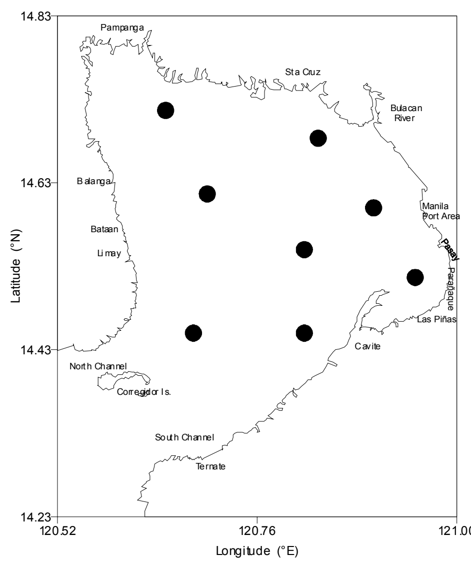



Dry Season, 1997-1998

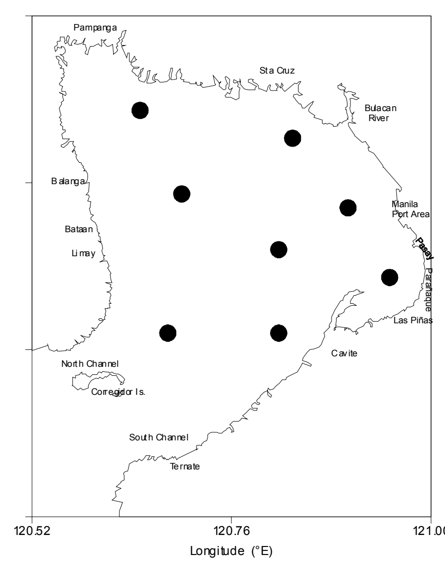
**Figure 38. RQs for Phosphate in Bottom Waters of Manila Bay and Seasonal Variations.**




Dry Season, 1996-1997




Wet Season, 1997




Dry Season, 1997-1998

where highest RQ levels were noted during the same period.

For ammonia, the certainty levels were low, i.e., less than five percent. This is consistent with the contour plots where $RQ_{Geomean}$ values were below one at all depths.

For phosphate, the certainty levels were very high, i.e., 40-87percent. This is again consistent with the contour plots and classed post maps where high RQs were noted and hot spots were identified at all depths.

## 4.9. DISSOLVED OXYGEN (DO)

### 4.9.1 Water Column

The data for DO was from the PRRP Report (PRRP,1999) and samples were taken at the same time period as the nutrient data. The criteria value (i.e., 5 mg/L) was from the DAO 34 (1990) for Class SC waters.

For DO, unlike other parameters, concentrations lower than the threshold value signal deteriorating environmental conditions. RQ, therefore, is not the ratio of MEC and PNEC but the reciprocal of the ratio, and the worst-case RQ is obtained using the lowest MEC.

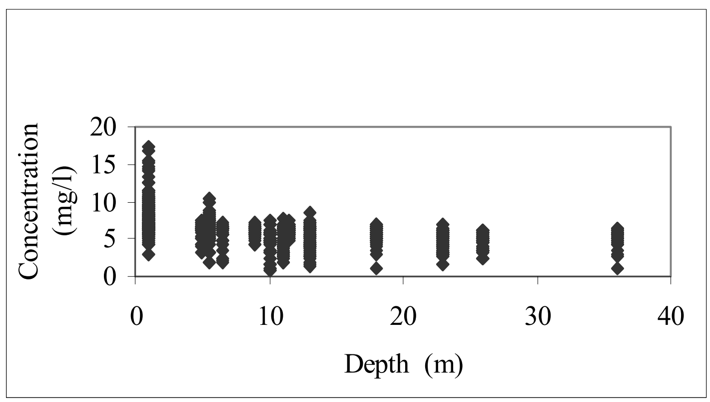
Figure 39 shows the scatter plot distribution of DO at the different sampling depths for the period 1996-1998. The scatter plot shows a marked DO depletion with depth with the steepest depletion occurring between the mid-depth and bottom levels.

The lowest MEC for DO (0.9 mg/L) was measured near the bottom at the station near the Bulacan River in September 1996 and generated a worst-case RQ of 5.6. The geometric mean of all measurements (5.78 mg/L; n = 769) gave an RQ equal to 0.87.

Table 41 shows the RQ ranges for DO at different sampling depths for the period 1996-1998:

Of the 257 data sets for DO at the surface water of Manila Bay, only three exceeded the critical RQ level of one. The exceedance occurred in 1996. In 1997, no data set exceeded the critical RQ level while in 1998, 3 data sets exceeded the critical RQ level. This essentially means that, in general, the inputs from oxygen-

**Figure 39. Scatter Plot of DO in Manila Bay.**



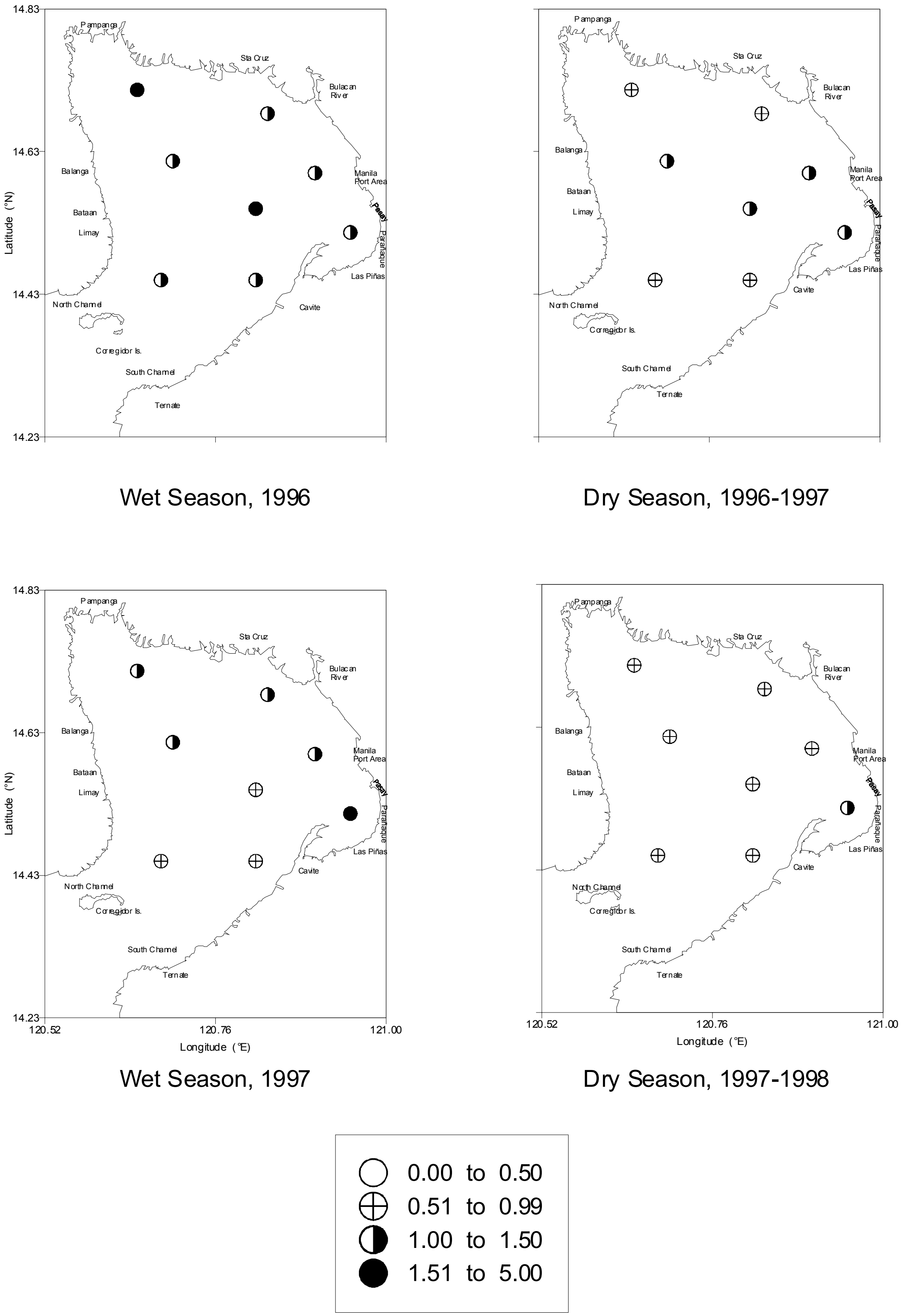

*Source: PRRP, 1999.*

**Table 41. $RQ_{Geomean}$ Ranges for Dissolved Oxygen.**

| Year | $RQ_{Geomean}$ Range | | |
|---|---|---|---|
| | Surface | Mid-depth | Bottom |
| 1996 | 0.60-0.78 (n=76) | 0.77-1.08 (n=73) | 0.98-1.42 (n=77) |
| 1997 | 0.59-0.72 (n=88) | 0.78-0.97 (n=88) | 0.92-1.37 (n=88) |
| 1998 | 0.68-0.78 (n=93) | 0.73-1.04 (n=93) | 0.90-1.17 (n=93) |

*Source of MEC: PRRP, 1999.*
*Source of PNEC: DAO 34, s. 1990.*

**Figure 40. RQs for DO in Bottom Waters of Manila Bay and Seasonal Variations.**



producing processes on the surface of Manila Bay still exceed the oxygen-consuming processes.

The yearly RQ range for the bottom layer of the water column is given in Table 41. About 51 percent of the data exceeded one. While the oxygen-producing processes are generally confined to the surface, the oxygen-consuming processes are most intensive near the sediment-water interface (PRRP, 1999). During the wet season of 1996, all of the areas covered by the PRRP sampling stations showed RQ > 1 (Figure 40). The worst DO conditions were found in the sampling point nearest the Pampanga River and the area near the bay's center. The highest RQs corresponded to samples collected from the upper half of the bay. During dry season of 1996-1997, the situation slightly improved and only the stations along the central belt of the bay exhibited RQ >1. During the wet season of 1997, the hot spots appeared at the stations nearest the eastern through the northern shore. During the dry season of 1997-1998, the water quality in terms of DO further improved with only the station nearest Pasay-Parañaque having RQ >1.

The station nearest Paranaque was worst in terms of DO, characterized by the high frequency of RQs >1. This was followed by the station near the mouth of Pasig River, station towards the center of the bay, station nearest Bataan and finally, the station near the Pampanga River outlet.

In general, the quality of the bottom of the water column of Manila Bay improved in terms of DO for the three-year period. Critical RQs were mostly encountered during the wet season than during the dry season of the three-year observation period.

**Uncertainty Analysis**

For DO in surface waters, the probability of RQ exceeding one was in the range 0-12.1 percent (S.D. range: 0-12.1). For mid-depth waters, the probability of RQ exceeding one was in the range 2-32 percent (S.D. range: 0.17-0.19). For waters at the bottom of the water column, the probability of RQ exceeding was is in the range 62-80 percent (S.D. range: 0.27-0.51). These findings are consistent with the classed post maps for the sampling period.

## 4.10. 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 river systems that are 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.

### 4.10.1. Nutrients

The maximum MECs for all the nutrient parameters (Table 42) 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 nitrate-nitrogen, however, applies only to lakes and reservoirs and similarly impounded waters and is more conservative.

All calculated maximum RQs for phosphate-P were greater than one in all river systems examined. Average phosphate-P RQs for the Cavite and

**Table 42. 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 | 4.24 | 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 | 1.22 | 18 |
| $NH_3$-N | 1.29 | 45.00 | No data | - | - |

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

Pampanga river systems were less than one while average RQs for Bulacan and Metro Manila river systems were 4.24 and 1.22, respectively. All maximum $NO_3$-N RQs for all the river systems were less than one. There are no environmental criteria for ammonia in the water column, thus the RQ value for this parameter could not be calculated.

Based on MECs, nitrogen in most of the river systems appears to have higher concentrations than phosphorus, but RQ values suggest that the level of phosphorus can pose a risk to the quality of the water column. Higher concentrations of phosphorus than nitrogen 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 phosphate 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 quantitatively their relative contributions. Reports of nutrient river loadings would be needed for such assessments.

**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. Raw data should be examined 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 $NO_3$-N and 0.4 mg/L for $PO_4$-P) but these were the only criteria available for fresh water. It would be useful to compare these values with other nutrient criteria for fresh water.

### 4.10.2. BOD/DO

All maximum RQ values for BOD and DO were greater than one (Table 43). Of the four river systems, the Metro Manila river system (Pasig River and major tributaries) had the highest BOD (RQ = 27) followed by the Bulacan river system (RQ = 17). Consequently, both river systems also gave the lowest DO (MEC = 0) in the water column. The $RQ_{Max}$ obtained for DO were very high (e.g. RQ = 500) and suggests a need for immediate action.

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

#### Uncertainty Analysis

The Monte Carlo simulation was applied to the DO data from the Cavite river system since the average RQ obtained was close to one. The results showed that DO has 30 percent probability of exceeding one (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 for each river from 1996 to 1998, which might have introduced some bias toward higher concentrations.

## 4.11. TOTAL SUSPENDED SOLIDS (TSS)

The data for TSS was from the PRRP Report (PRRP, 1999) and samples were taken at the same

**Table 43. 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 23, s. 1990, for Class C waters.*

time period as the nutrient data (1996-1998). The criteria value (i.e., 50 mg/L) was from the interim standard of the Department of Environment of Malaysia (MPP-EAS, 1999b). Suspended solids refer to organic and inorganic solid particles suspended in seawater and can be filtered through a 0.45 µm membrane.

The highest MEC of TSS in Manila Bay (1,048 mg/l) was observed in the monitoring station near the Manila Port Area and Pasig River in April 1996 and gave the worst-case RQ of 21. The geometric mean of all observations (n= 771) was 23.32 mg/L which gave an RQ of 0.5.

Table 44 shows the $RQ_{Geomean}$ ranges for TSS at different sampling depths for the period 1996-1998.

The $RQ_{Geomean}$ for TSS in the waters of Manila Bay exceeded the critical level of one at all sampling depths in 1996. The RQ values, however, sharply decreased in 1997 and 1998 indicating an improvement in the water quality of the bay in terms of TSS for the three-year period. In 1996, the hot spot surface waters were in the vicinity of Metro Manila and Bulacan. Other areas of concern were in the middle of the Bay as well as the northern portion facing Bulacan and Pampanga, and the southwestern tip facing Bataan (Figure 41).

In 1996, the highest values of TSS for bottom waters were observed in the northern portion of the Bay facing Bulacan and Pampanga (Figure 42). There were no evident seasonal effects in the levels of TSS in the water column.

**Uncertainty Analysis**

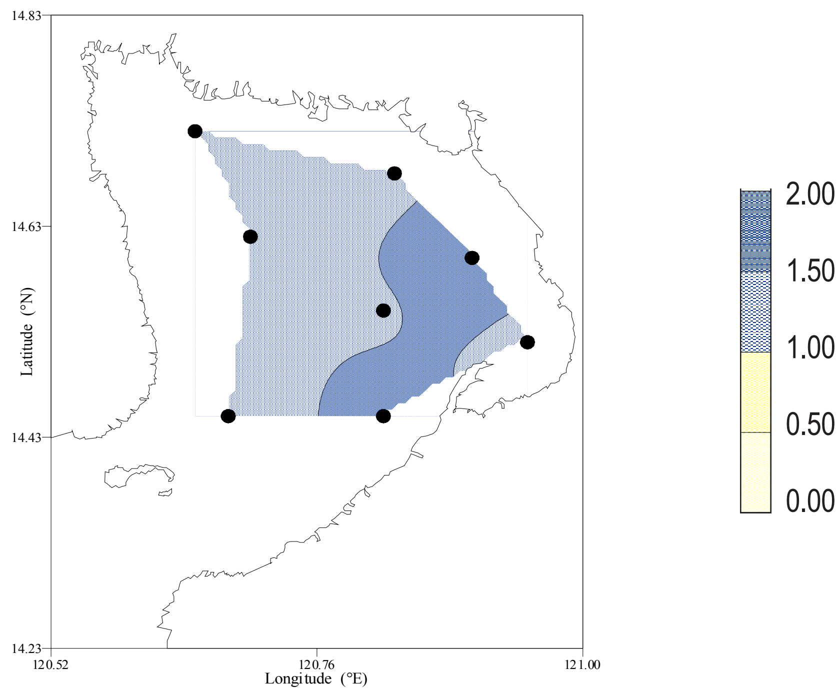
The threshold value (i.e., 50 mg/L) used was an interim value from Malaysia. The marine water quality criteria of the Philippines as per DAO 34 (1990) was not used due to Manila Bay's conditions. The Philippine criteria specifies that TSS concentrations should not be 30 mg/L greater than the annual average. When this PNEC was applied, all $RQ_{Geomean}$ values were found to be below the critical level; thus, the Malaysian interim criteria was deemed more conservative. In the ASEAN marine water quality criteria the TSS concentrations should not be 10 percent 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. In the case of Manila Bay, there is so much anthropogenic influences that the "natural" seasonal variation will be very difficult to establish.

**Table 44. $RQ_{Geomean}$ Ranges for Total Suspended Solids.**

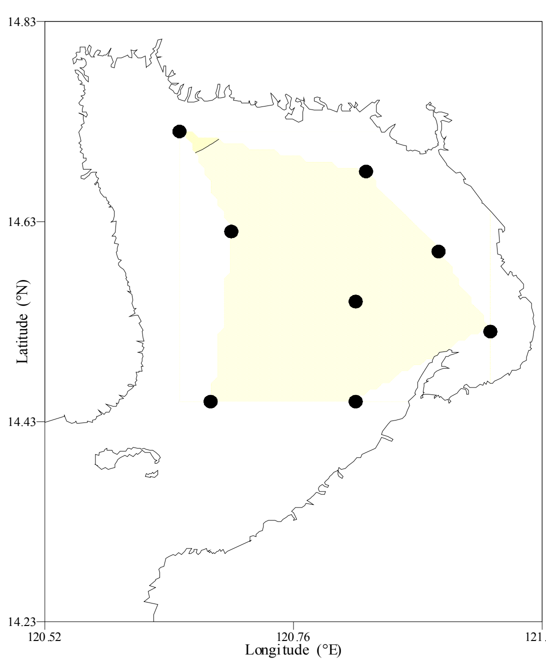
| Year | RQ Range | | |
|---|---|---|---|
| | Surface | Mid-depth | Bottom |
| 1996 | 1.23-2.04 (n=76) | 1.29-1.50 (n=73) | 1.37-1.60 (n=77) |
| 1997 | 0.31-0.53 (n=88) | 0.34-0.52 (n=88) | 0.40-0.60 (n=88) |
| 1998 | 0.31-0.54 (n=93) | 0.32-0.58 (n=93) | 0.48-0.63 (n=93) |

*Source of MEC: PRRP, 1999.*
*Source PNEC: MPP-EAS, 1999b.*

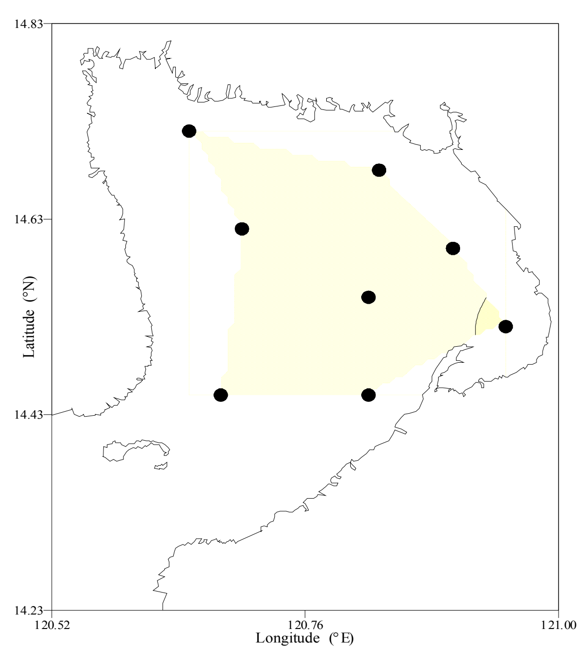
**Figure 41. RQs for Total Suspended Solids in Surface Waters of Manila Bay.**




Dry Season, 1996

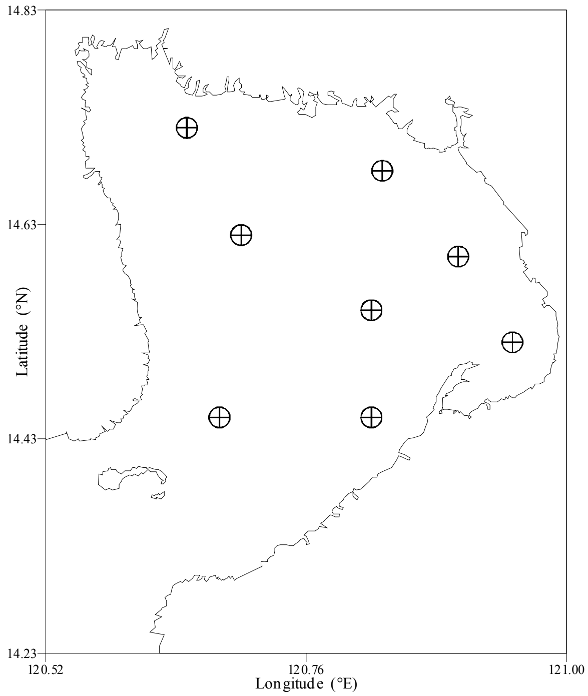



Wet Season, 1997

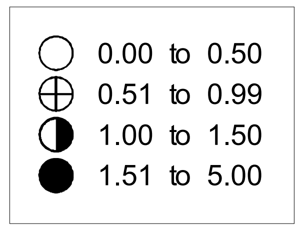


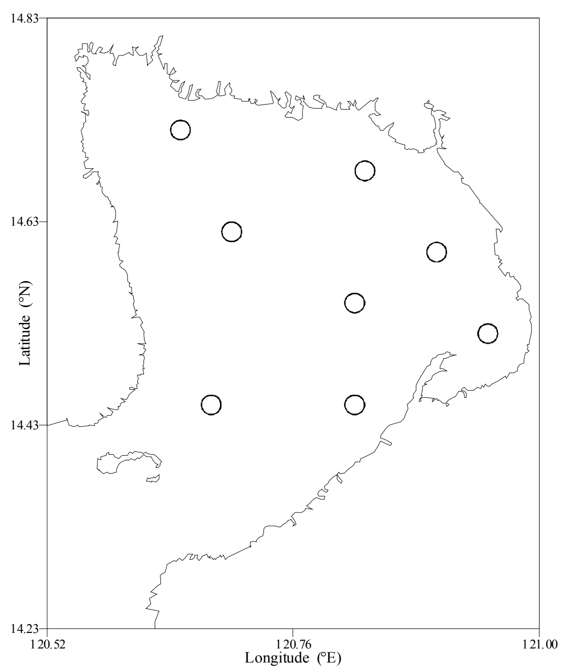

Dry Season, 1998

**Figure 42. RQs for Total Suspended Solids in Bottom Waters of Manila Bay.**

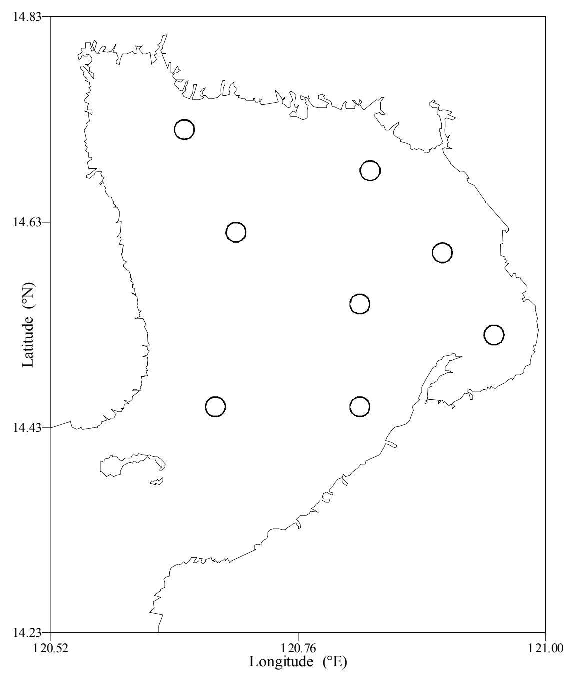



Dry Season, 1996-1997




Wet Season, 1997




Dry Season, 1997-1998

## 4.12. POLYCYCLIC AROMATIC HYDROCARBONS (PAHS)

The data used in Table 45 came from two sources: the study by Santiago (PRRP, 1997) and the PRRP report (1999). The data from Santiago (1997) were gathered from ten stations at the western section and 16 stations at the eastern section of the Bay in 1996. The PRRP (1999) data were taken from ten 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 HK ISQV (EVS, 1996).

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 also clearly demonstrated that PAH levels in the eastern area which is 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 and suggesting localized risks The PRRP study (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 health effects in various marine organisms. Consumption of aquatic organisms contaminated with PAHs may also cause cancer in humans.

Santiago (1997) identified the PAHs in Manila Bay sediments as coming from petrogenic and pyrolytic sources. Petrogenic sources PAHs come from oil discharges from ships, refineries, and industries while 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.

Sixteen PAHs were also analyzed in oyster from Malolos, Bulacan and Naic, Kawit, and Bacoor, Cavite on September 1996 (PRRP, 1999). All reported values were less than the detection limit of 0.100 $\mu g/g$ (dry basis) and no TDIs were available so RQs were not computed.

**Table 45. PAHs in Sediments from Manila Bay.**

| Agent | $MEC_{Geomean}$ *(µg/g)* | $MEC_{Max}$ *(µg/g)* | PNEC[1] *(µg/g)* | $RQ_{Geomean}$ | $RQ_{Max}$ |
|---|---|---|---|---|---|
| **Santiago (1997)** | | | | | |
| Benzo(a)Pyrene | 0.01 | 0.11 | 0.4300 | 0.03 | 0.25 |
| Chrysene | 0.01 | 0.12 | 0.3840 | 0.02 | 0.30 |
| Dibenzo(a,h) Anthracene | 0.002 | 0.01 | 0.0634 | 0.03 | 0.16 |
| Total PAH* | 0.71 | **7.18 | 4.0220 | 0.18 | 1.78 |
| **PRRP (1999)** | | | | | |
| Dibenzo(a,h) Anthracene | 0.02 | 0.064 | 0.0634 | 0.40 | 1.00 |

**TPAH = summation of 18 individual PAH*
***Next highest MEC*
*Sources of MEC: Santiago, 1997 and PRRP, 1999*
*Source of PNEC: EVS, 1996*

## 4.13. OIL AND GREASE

### 4.13.1. Water Column

The oil and grease concentrations in water were recorded in 13 different sites in Manila Bay in 1985, 1992 and 1993 (BFAR, 1995). Records show that there was no significant increase in oil and grease concentration over the period indicated. The criteria value used as PNEC, i.e., 3 mg/L, was taken from the DAO 34 (1990) for Class SC waters. This value pertains to the organic fraction extract. However, some oil and grease measurements were reported using the water-soluble fraction and should have been used with the appropriate 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 46). These observations may be explained by the presence of oil refineries in nearby coastal areas in Mariveles and Limay, Bataan. $RQ_{Geomean}$, however, was computed to be low at 0.5 with mean oil and grease concentration in water at 1.40 mg/L.

In most of the stations, the allowable level of 3.0 ppm was exceeded at least once for 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.

More recent data collected in August 2001 indicated that the PNEC of 3 mg/L was exceeded in all the five sampling locations in the Bay. The highest values were in the lower portion of the Bay while the lowest RQs were noted along the western portion of the Cavite City peninsula. For the more recent 2001 data, $RQ_{Max}$ was 18 while $RQ_{Geomean}$ was 8.52. Even the best-case RQ exceeded one ($RQ_{Min}$ = 2.8), signaling worsening conditions of oil and grease in the bay.

On a global scale, the primary inputs of oil into the marine environment are believed to originate from land-based sources particularly refineries, municipal and institutional 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. A major contributor to the oils in Manila Bay are oil spills from land and sea-based sources which is presented in the next section.

**Uncertainty Analysis**

The $RQ_{Geomean}$ based on data collected in 1995 indicates that the levels of oil and grease in the Bay were low. The $RQ_{Max}$ indicates that oil and grease exceeds the threshold value in certain locations although the high values still seemed incompatible with the amounts of oil and grease that are visually observed

**Table 46. Oil and Grease in Water (PNEC = 3 mg/L).**

| MECs | Concentration, mg/L | RQ |
|---|---|---|
| Maximum | 16.55 | 5.5 |
| Minimum | 0.01 | 0.003 |
| Geomean | 1.40 | 0.5 |

*Source for MEC: BFAR, 1995*
*Source for PNEC: DAO 34, s. 1990 for Class SC waters*

at near-shore areas especially near the ports. Oil and grease in offshore locations in the Bay may not be elevated but measurements in nearshore areas, especially near the point sources, may be higher and should be further assessed. The most recent data show that the PNEC of 3 mg/L was exceeded in all of the five stations. Questions, however, can be raised on the comparability of these data sets and the PNEC value since ambient oil and grease concentrations were measured by partition-infrared method while the criteria value was derived using the partition-gravimetric method.

There were 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 pose to the ecosystem.

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

The data generated for oil and grease in the water column (BFAR, 1995) have been assigned a score of three for data quality. Despite this, the data values were included in the refined risk assessment in the absence of any other data sets.

## 4.14. OIL SPILLS

The Philippine Coast Guard has recorded a total of 48 oil spills in Manila Bay and its tributaries between the period 1990 to 2001. These incidents/ accidents are listed in Table 47 including the sources, data on the oil product spilled, areas affected and quantities reported. Other oil spills may have gone unrecorded, especially the regular low-volume discharges.

The highest incidence of spills occurred in the area near Manila with 19 incidents causing the release of a total volume of 200,038,278 L and 1,837 barrels of oil. This number of accidents can be attributed to the fact that an international port is located in Manila. Pasig River and its tributaries ranked second with 16 incidents, with a total volume of 17,300 L of oil spilled. Bataan, where an oil refinery and ship repair facilities are located, ranked third as to the number of spills with 12 occurrences involving a total volume of 203,366 L and 28 barrels oil spilled. Of the 48 oil spill incidents reported, 24 were sea-based (i.e., from ships) while the rest were either land-based or undetermined. The most frequent oil spill incidents occurred in 1995 followed by 1996 and 1997 (Figure 43).

The volume of oil spilled from 1990 to 2001 in different areas is shown in Figure 44. For the 11-year period, the largest oil spill occurred in Bataan, followed by Manila, and then Corregidor. Oil spills in Bataan are primarily due to shipping activities and discharges from industrial establishments along its coast. Oil spills in Manila are attributed to shipping (in the North and South Harbors), oil terminals, and industries, while that in Corregidor is traceable to sea-based activities. At least eight oil spill incidents occurred in Manila South Harbor alone between 1990 and 2001.

The largest single incident of oil spilled into the bay was 747 mt. Three of the four spills with the largest volume discharged (200,000 - 747,000 L) were from ships (MT Mary Anne, MV Princess of the Orient and MT Fernando J-1) as shown in Table 47. The largest amount of oil was spilled in 1999 and was mainly traceable to sea-based sources, i.e., from ships (Figure 45).

**Table 47. List of Oil Spill Incidents in the Manila Bay Area in the 1990s.**

| Source | Date | Oil Product Spilled | Area Affected | Quantity Reported, L |
|---|---|---|---|---|
| MT Fernando J-1 | 24 Jan 90 | Industrial fuel oil | Lamao, Limay, Bataan | 200000 |
| MV Al Taludi | 2 Aug 90 | Bunker oil | Manila | 2100 |
| Bataan Refinery Corp. | 22 Oct 90 | Bunker oil | Limay, Bataan | 5 barrels |
| MV Carlota | 8 Mar 91 | Oily water | Mariveles, Bataan | 1050 |
| MT Ivy | 5 Apr 91 | Industrial fuel oil | Lamao, Limay, Bataan | 20 barrels |
| MT Nazal-I | 20 Dec 91 | Auto diesel oil | Pier 8, Manila | 10500 |
| Sea Oil Petroleum Corp. | 2 Sep 92 | Bunker oil | Manila | 420 |
| MT Bacolod City | 22 Sep 92 | Bunker oil | Manila | 100 |
| PNOC/PSTC | 8 Dec 92 | Bunker oil | Pandacan, Manila | 420 |
| Undetermined sources | Feb 93 | Bunker oil | Bgy. Marina, Mariveles, Bataan | Und. Amount |
| MT Calumpit | 19 Apr 93 | Lube oil | Petron Terminal Pandacan, Manila | 4200 |
| PBRC | 19 Apr 94 | Bunker oil | Limay, Bataan | 420 |
| Petro Queen | 8 Aug 94 | Bunker oil | Manila Bay | 670 barrels |
| Discovery Industrial Corp. | 13 Aug 94 | Bunker oil | Pasig River | 600 |
| MV Cebu City | 02 Dec 94 | Bunker oil | Manila Bay | 3000 |
| Allied Thread Co. | 11 Jan 95 | Bunker oil | Marikina River | 400 |
| Rockwell Thermal Plant | 17 Jan 95 | Bunker oil | Pasig River | 63000 |
| Republic Asahi Glass | 28 Feb 95 | Bunker/fuel oil | Pinagbuhatan, Pasig City | 2000 |
| Puyat Steel Corp. | 3 Mar 95 | Bunker/fuel oil | Pasig River, Mandaluyong City | 50-70 |
| Pacific Glass Product | 19 Mar 95 | Bunker oil | San Juan River | 1400 |
| PISCOR | 20 Mar 95 | Diesel oil | Manggahan, Pasig City | 20 |
| MT Pandi | 12 May 95 | Industrial fuel oil | Limay, Bataan | 500 |
| Resin Corp. | 15 Jul 95 | Industrial fuel oil | Pasig City | 3000 |
| Warner Lambert Corp | 21 Jul 95 | Industrial fuel oil | Pasig City | 2000 |
| MV Wilcon X | 22 Sep 95 | Industrial fuel oil /Bunker oil | Pier 18, Manila | 2000 |
| Integral Chemical Corp. | 14 Oct 95 | Diesel oil | Mandaluyong | 100 |
|  | 30 Jan 96 | Bunker oil | Tondo, Manila | 1000 |
| San Jose Glass Corp. | 02 Feb 96 | Bunker oil | Mandaluyong City | 150 |
| MT Pacific Leader | 22 July 96 | Crude oil | Limay, Bataan | 76 |
| MT Malinao | 04 Aug 96 | Industrial fuel oil | Limay, Bataan | 3 barrels |
| Sea Oil Petroleum Corp | 08 Aug 96 | Bunker oil | Pasig River | 400 |
| MV Badger | 14 Aug 96 | Bunker oil | Pier 8, North Harbor | 38 |
| Petron Terminal | 17 Sep 96 | Bunker oil | Petron Terminal, Pandacan | 60 |
| Unknown | 17 May 97 | Crude oil | Lamao, Bataan | 60 |
| OTC Barge Brazil | 03 Jun 97 | Oily mixture | Pasig River | 800 |
| Unconfirmed source | 05 Oct 97 | Bunker oil | Pier 6, Manila | 14500 |
| Planters Product | 15 Oct 97 | Oily mixture | PPI Pier, Limay, Bataan | 1260 |
| MV Princess of the Orient | 21 Sep 97 | Bunker oil | Corregidor | 5000000 |
| MT Sea Brothers I | 19 Mar 99 | Bunker oil | South Harbor, Manila | 420 tonnes |
| MT Mary Anne | 1 Jun 99 | Bunker oil | Limay, Bataan | 747 tonnes |
| MT Christian Albert | 04 Jan 00 | Bunker oil | Pier 4, SH, Manila | 400 |
| Baseco Shipyard | May 00 | Bunker oil | Engineering Island | Und. Amount |
| Undetermined source | 16 Sep 00 | Bunker oil | Morong, Bataan | Und. Amount |

Source: PCG, 2002 (unpublished report).

**Figure 43. Oil Spill Frequency in Manila Bay and Tributaries (1990-2001).**

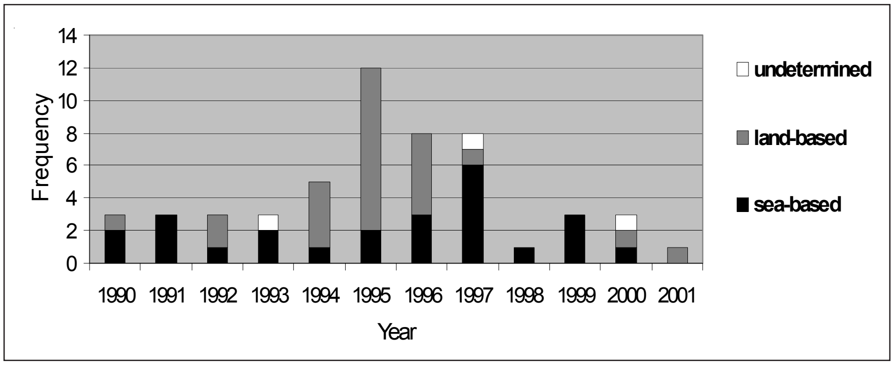
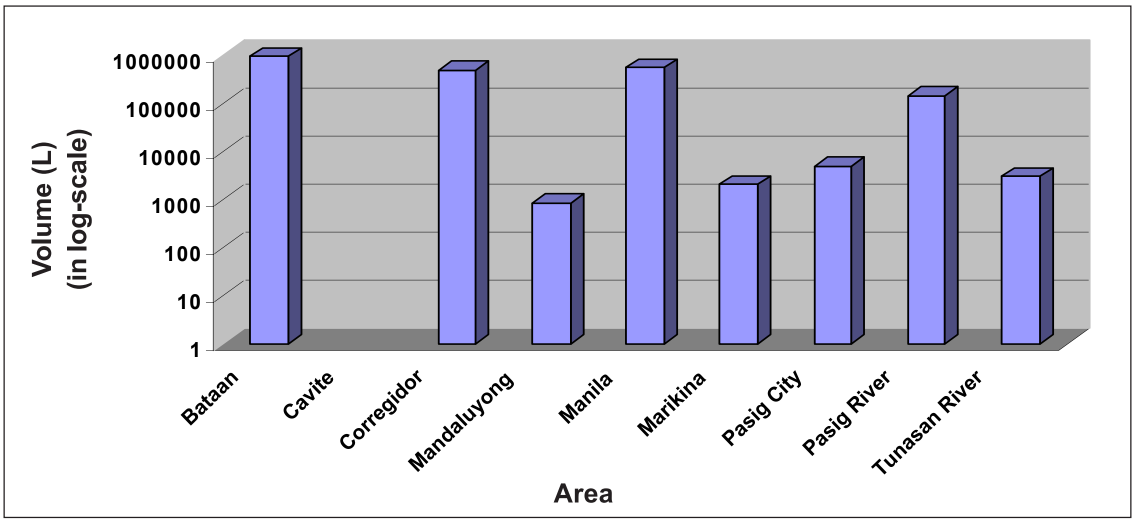
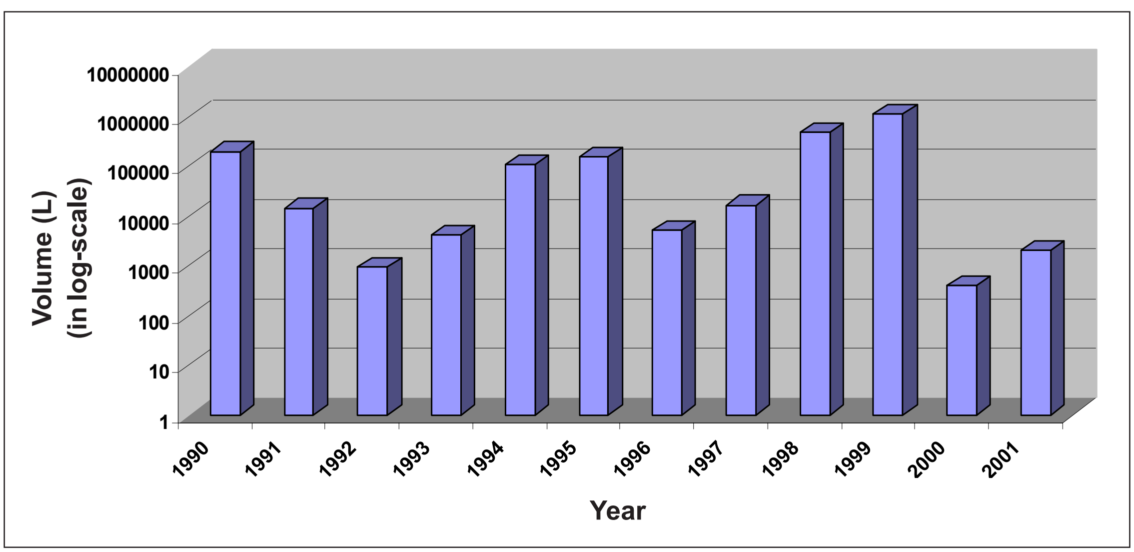



**Figure 44. Volume of Spilled Oil per Area (1990-2001).**




*Volume for Cavite undetermined.*

**Figure 45. Volume of Spilled Oil per Year (1990-2001).**




*Source: EMB-DENR, 1996.*

## 4.15. ORGANOTINS

Tributylin compounds (TBT) frequently used in anti-fouling treatment of ships have been implicated as the causative agent in a number of growth anomalies observed in marine animals. TBT is particularly toxic to certain mollusks, for which NOELs (no observable effect levels) for several species are very low, i.e., below 0.001 g TBT/L, making it the most toxic compound ever deliberately released to the sea (Goldberg, 1986).

Imposex, defined as the development of a penis and/or vas deferens in female gastropods, has been linked to the presence of the biocide tributylin (TBT). The first incidence of imposex in female gastropods was discovered in *Nucella lapillus* in 1969 (Balber, 1970). It took a decade before this incidence was linked to TBT (Smith, 1981). It also causes shell thickening in oysters (Alzieu *et al*., 1986). Imposex has been observed in 132 species of gastropods (Fioroni *et al*., 1991).

Bech (2000) has summarized the other effects of TBTs to marine organisms. *Crassostrea virginica* had lower resistance to protozoan pathogen (*Perkinsus marinus*) after exposure to sub-lethal concentrations of TBT oxide (Fisher *et al*.,1999 ). Lawler and Aldrich (1987) further observed that oxygen consumption, feeding rate, and growth of *Crassostrea gigas* spat were harmed by sub-lethal concentrations of TBTO. Ruiz *et al.* (1995) found that *Scrobicularia plana* has suffered ill effects in the embryonic development due to TBT levels above 0.2 g tin per liter, which is lower than the historical levels at many locations in Europe.

The catastrophic effect of TBT on the oysters in France triggered the first legislation to reduce the use of TBT in 1982. Since then, similar legislation has been implemented in most western countries. This resulted in a decrease of TBT in water columns and sediments and the recovery of different populations of organisms, such as *Nucella lapillus* (Alzieu *et al.*, 1986 ).

In Southeast Asia, the use of TBT in anti-fouling paints since the mid 1960's has not been regulated, despite the fact that TBT has negative effects on growth, survival and recruitment of commercially important mollusks.

There has been no published work on the effect of TBTs on marine organisms in Southeast Asia except that of Bech's study in Thailand (1999). *Thais distinguenda*, *Thais bitubercularis* and *Morula musiva* were chosen as indicator organisms and their differences in sensitivity to TBT in terms of imposex frequency and relative penis size index (RPSI) were examined at five different stations along the south east coast of Phuket Island in Thailand.

No data on the effect of TBT on mollusks in the Philippines are available. There is a need to establish, or at the very least estimate, the levels of TBT in coastal waters associated with its use as anti-fouling agent.

**Table 48. Marine Debris Collected in NCR and Regions 3 and 4.**

| Region | Province/Municipality/City | Year 1999 | |
|---|---|---|---|
| | | Distance covered, km | Debris collected, kg |
| NCR | Manila, Makati, Pasay, Quezon | 23.92 | 91,537.20 |
| 3 | Bataan (Balanga, Limay, Mariveles) | 81.02 | 11,053.00 |
| | Bulacan (Calumpit, Hagonoy, Malolos, Sta. Cruz) | 33.84 | 3,319.00 |
| 4 | Cavite (Cavite City, Naic, Maragondon) | 3.55 | 10,941.00 |

*Source: IMA/CMC/USAID/DENR, 1999*

## 4.16. MARINE DEBRIS

### 4.16.1. Water Column

Marine debris is defined as any object, i.e, wood, metal, glass, rubber, plastic, cloth or other man-made item that has been lost or discarded into the marine environment. These solid wastes may have been intentionally dumped, accidentally dropped or indirectly deposited from land or sea. Depending upon its composition, marine debris may sink to the floor, drift in the water column, or bob on the surface of the sea. This floating litter poses a unique hazard to wildlife, recreation, tourism, fisheries and humans. It is a problem not only on land but for the marine ecosystem as well.

There is currently no systematic nor sustained effort to establish the amount and effects of marine debris or solid wastes in Manila Bay. However, data generated by NGOs and partner groups and agencies (e.g., International Marinelife Alliance, Center for Marine Conservation, etc.) during the 1999 International Coastal Cleanup shows the amount and type of marine debris in Manila Bay in 1999 (Tables 48 and 49).

In terms of type, the debris most commonly found along the coast of Manila Bay is shown in Table 49.

The solid waste generation rate in the Metro Manila area and other areas bordering Manila Bay is estimated at 6,545.66 t/day as of year 2000(JICA-MMDA, 1997). The generation rate has been steadily increasing with the increase in population.

**Uncertainty Analysis**

The RQ approach in determining risks cannot be applied to marine debris. The problem of marine debris is, however, very relevant to Manila Bay. Visual observations show the proliferation of marine debris emanating primarily from land, especially in the coastal zones and in the mouths of rivers draining into Manila Bay.

## 4.17. HARMFUL ALGAL BLOOM (RED TIDE)

### 4.17.1. Introduction

The first recorded occurrence of toxic algae (red tide) in Manila Bay was on August 19, 1988 when Paralytic Shellfish Poisoning (PSP) episodes were observed in the coastal communities bordering the bay. *Pyrodinium bahamense* var. *compressum*, a species of marine dinoflagellate, was identified as the organism responsible for the PSP syndrome. Green mussels attained PSP toxin levels of 1,005-

**Table 49. Marine Debris Types in Manila Bay's Coastal Areas.**

| Debris Type | Total No. Reported | % of Total Debris Collected |
|---|---|---|
| Plastic foodbag/wrappers | 16,017 | 23.34 |
| Other plastics | 12,777 | 18.62 |
| Plastic pipes | 5,413 | 7.89 |
| Straws | 4,425 | 6.45 |
| Plastic caps, lids | 3,459 | 5.04 |
| Other plastic bags | 2,718 | 3.96 |
| Cigarette butts | 2,502 | 3.65 |
| Fishing nets | 1,984 | 2.89 |
| Beverage soda plastic | 1,856 | 2.71 |
| Other bottles | 1,776 | 2.59 |
| Foamed plastic cups, utensils | 1,612 | 2.35 |
| Diaper | 1,432 | 2.09 |

*Source: IMA/CMC/USAID/DENR, 1999*

μg/100 g of shellfish meat. Shellfish ban was imposed from August until December 1988. About 65 PSP cases with four deaths were reported during that time. The negative impact of the occurrence of toxic *Pyrodinium* in terms of public health and economics was enormous since the Bay has a thriving shellfish industry and is also very close to the country's commercial and trade centers. Commercial fishing boat operators incurred an estimated loss of US$809,524 during the five-month ban on shellfish harvesting in 1988 (Robles, 1988).

In July 1991, toxic *Pyrodinium* blooms recurred and consequently shellfishes, particularly green mussels, were positive for PSP toxin. People in coastal villages were again victims of PSP, with 73 PSP cases recorded.

Aside from *Pyrodinium bahamense* var. *compressum*, other harmful algae that have been detected in Manila Bay are shown in Table 50.

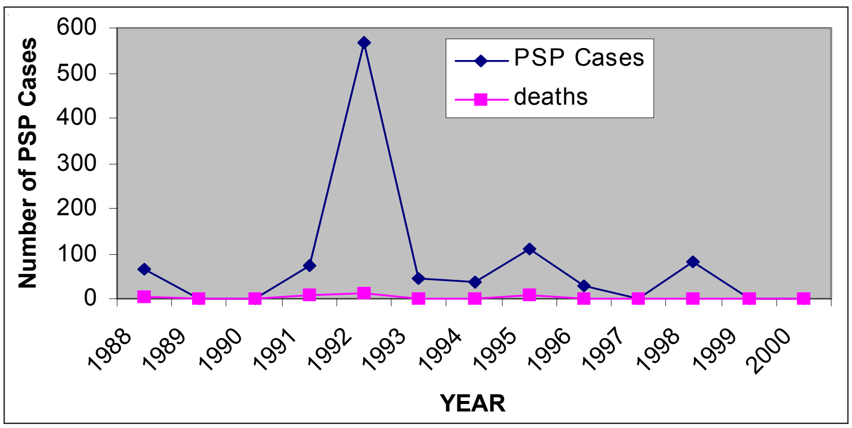
The results of the monitoring from 1991 to 2000 showed a trend/pattern in the bloom formation of *Pyrodinium bahamense* var. *compressum* and the occurrence of PSP toxin in shellfish (Bajarias and Relox, 1996 and Azanza and Miranda, 2001). Observations made during 1991 to 2000 show that the major peaks of *Pyrodinium* blooms have been occurring during July and August of each year which are the months with maximum amount of rainfall. Previous studies conducted in Manila Bay revealed that blooms of *Pyrodinium bahamense* var. *compressum* occur at the onset of the rainy season after a warm dry period which increased thermal stratification and vertical stability of the water column (Azanza *et al.*, 1998, Villanoy *et al.*,1996; Bajarias and Relox, 1996). Concurrently high levels of toxicity in shellfish particularly green mussels were also noted, which resulted in the massive paralytic shellfish poisoning (PSP) incidents. During the *Pyrodinium* occurrence in the bay from 1988 to 2000, a total of 1,108 PSP cases with 38

**Table 50. Other Potentially Harmful Algal Species Reported in Manila Bay.**

| Algal Species | Potential Harmful Effects | Reference |
|---|---|---|
| *Alexandrium sp.* | Paralytic Shellfish Poisoning | Azanza, R.V. & L.M. Miranda 2001 , GEOHAB, April 2001 |
| *Pyrodinium bahamense var. compressum* | Paralytic Shellfish Poisoning | Azanza, R.V. & L.M. Miranda 2001 , GEOHAB, April 2001 |
| *Goniodoma sp.* | Allelopathy | Azanza, R.V. & L.M. Miranda 2001 , GEOHAB, April 2001 |
| *Dinophysis spp.* | Diarrhetic Shellfish Poisoning | Azanza, R.V. & L.M. Miranda 2001 |
| *Gymnodinium catenatum* | Paralytic Shellfish Poisoning | Azanza, R.V. & L.M. Miranda 2001 , GEOHAB, April 2001 |
| *Gymnodinium sanguineum* | Fish killer | Azanza, R.V. & L.M. Miranda 2001 |
| *Cochlodinium sp.* | Haemolytic, hepatoxic, osmoregulatory effects and other unspecified toxicity | Azanza, R.V. & L.M. Miranda 2001, GEOHAB, April 2001 |
| *Polykrikos kofoidii* | Fish killer | Azanza, R.V. & L.M. Miranda 2001 |
| *Prorocentrum micans* | Hypoxia, anoxia | Azanza, R.V. & L.M. Miranda 2001 , GEOHAB, April 2001 |
| *Prorocentrum lima* | Production of foam, mucilage, discoloration, repellent odor | Azanza, R.V. & L.M. Miranda 2001 , GEOHAB, April 2001 |
| *Noctiluca scintillans* | Production of foam, mucilage, discoloration, repellent odor | Azanza, R.V. & L.M. Miranda 2001 , GEOHAB, April 2001 |

fatalities have been recorded (Figure 46). The number of recorded PSP cases peaked in 1992. Subsequently, a declining trend was observed, presumably due to the high level of awareness of consumers to refrain from eating PSP-contaminated shellfish during outbreaks of toxic *Pyrodinium* blooms.

**Figure 46. Paralytic Shellfish Poisoning (PSP) Cases in Manila Bay, 1988-2000.**




*Source: IACEH-DOH*

### 4.17.2 Factors Favorable for Harmful Bloom

The RQ approach is not directly applicable to assessment of risks due to toxic algae. Successful prediction of the location, timing and extent of *P. bahamense* bloom based on measurements of physico-chemical, hydrological and meteorological data in and of the bay can be construed as the equivalent of prospective risk assessment for toxic HAB in Manila Bay. The risk factors must be identified from which suitable management approaches can be applied for the mitigation of the harmful impacts of toxic algal bloom in the bay. Inasmuch as the environmental factors affecting the bloom are site- and species-specific (Smayda 1997), the formulation of a predictive model for the occurrence of toxic algal bloom in Manila Bay should be based on the specific physico-chemical, biological, hydrological and meteorological conditions in the bay that would be suitable for the initiation, propagation and decline of the bloom (Table 51).

**Table 51. Some Physico-Chemical Factors Favorable for *Pyrodinium* Growth.**

| Reference | Environmental Conditions | | | |
|---|---|---|---|---|
| | Salinity (ppt) | Temperature (°C) | Irradiance ($uEm^{-2}s^{-1}$) | Nutrients |
| Laboratory studies on *P. bahamense* (Usup and Azanza) | 20-36 | 22-34 with optimum at 26 °C | 50 to 150 (laboratory) | soil extracts nitrate and urea organic and inorganic phosphorus limited ability to utilize organic substances |
| *Pyrodinium* bloom in Manila Bay, 1992-1994 (Bajarias and Relox) | 21-35 | 24.5-31.5 | | |
| Western Samar Bloom, (Estudillo & Gonzales, 1984) | 31.15-33.88 (surface) 33.73-35.28 (bottom) | 29.6 - 32.5 ( surface ) 26.4 - 29.8 (bottom) | | |

Bloom initiation in the bay can come from vegetative cells or from resting cysts in the sediment. The relative importance of resting cysts as opposed to vegetative cysts in initiating the bloom is still uncertain (Usup and Azanza, 1998). If the resting cyst could provide the inoculum for the bloom, mapping of the cyst population in different areas of the bay may indicate the possible areas more susceptible to bloom recurrence. The absence of cysts in the surface sediment, however, does not indicate that the area is free from the threat of toxic blooms (Anderson and Wall, 1978). Areas which could be sources of cysts of the organisms, hence could start *Pyrodinium* blooms, have been identified as Bataan and Cavite (Corrales and Crisostomo, 1996, Furio *et al.*., 1996, Azanza andMiranda, 2001).

Bloom occurrence in the bay is usually at the end of summer. It is usually dispersed according to the direction of water movement which, in turn, is affected by meteorological conditions in the bay. During the past blooms, it was observed that the *Pyrodinium bahamense* cells were dispersed northward, eastward and then southward. Measurable cell concentrations may occur as early as late March and grow profusely until July. Blooms were usually terminated towards the end of southwest monsoon. Villanoy *et al.* (1996) have hypothesized that during the northeast monsoon, high turbulence caused the strongest vertical mixing resulting in strong resuspension of sediment and cysts. During this period, suspended cysts could not start the bloom because of the unfavorable environment, i.e. low temperature and low nutrient. Reduced light due to strong water mixing could also prevent cyst germination. At the end of summer, germination and start of bloom could be possible because of higher temperature and higher nutrient.  In addition, turbulence is weak. During the southeast monsoon, the bloom is maintained by the stable subsurface water and less vertical mixing. (Villanoy *et al.*, 1996).

### 4.17.3. Man-made Contributions to the HAB Problem

In addition to the natural environmental factors mentioned, the effects of pollution on the occurrence or recurrence of algal bloom cannot be discounted. It is now firmly established that there is a direct correlation between the number of red tides and the extent of coastal pollution measured either in terms of chemical oxygen demand of effluents as in Japan, or the population density in a watershed as in Hong Kong (Anderson, 1989). In addition, the use of coastal waters for shellfish farming may actually enrich the water from the food and excretion of the cultured species, supplying the nutrients to sustain the bloom.

Other human activities, such as the discharge of ballast from ships and the transport of live aquaculture stock, are suspected to have resulted in the introduction of alien species, including those responsible for HABs, into other areas. For example, the dinoflagellate *Heterocapsa circularisquama* is thought to have been introduced from tropical or sub-tropical waters through transfer of stocks of juvenile oysters, and to have spread within Japan in subsequent years by movement of oyster spat to other locations. The only well-documented case of human-assisted transfer of a harmful species is the introduction of *Gymnodinium catenatum* to Tasmania, probably via ballast water discharge (McMinn *et al.* 1977). This aspect can be considered in the management/monitoring of HABs in Manila Bay and other areas.

### 4.17.4. Toxicity Risk Assessment

In the past events of toxic bloom in the bay, there has been a direct correlation between *P. bahamense* cell density and mussel toxicity as shown in Table 52.

**Table 52. Relationship Between Cell Density of *P. bahamense* and Toxin Levels in Mussels.**

| Month | Cell Density (cells/L) | Toxin level (μg/100g) |
|---|---|---|
| January | 4 | 0 |
| February | 10 | 0 |
| March | 7 | 0 |
| April | 0 | 0 |
| May | 22 | 0 |
| June | 127 | 56 |
| July | 144 | 793 |
| August | 778 | 1272 |
| September | 430 | 2291 |
| October | 4 | 379 |
| November | 3 | 144 |
| December | 153 | 49 |

*Source: BFAR data, Bataan, 1998 (unpublished)*

It has been shown also that the *P. bahamense* organisms in the bay produced a group of toxins collectively called saxitoxin. The estimated human lethal dose is 1 mg orally. The toxins are accumulated by shellfish to a level toxic to humans but not toxic to the organism. These toxins cause paralytic shellfish poisoning in humans. The number of fatalities and illnesses have already been discussed (Figure 46).

The standard method of detection for algal toxin in most seafood-monitoring programs is the mouse bioassay and this is the method for toxin detection in use in the country. The mouse bioassay has several disadvantages, such as insensitivity (1.0 MU/ml), imprecision (20 percent error), and the need to maintain a mouse colony, and runs into the ethical objections against animal experiments in some countries. The US FDA has set a maximum level of poison in fresh, frozen or canned shellfish of not more 400 MU (about 80 μg) per 100 g of shellfish tissue. The Philippines has set the limit to half of the US limit (40 μg per 100 g of shellfish tissue). Considering that the limit of detection of mouse bioassay is 37 μg per 100 g of shellfish tissue, its use puts public health at risk and places the shellfish industry at risk of an uncertain basis for closure of harvest areas.

A rapid and sensitive assay to complement the current live mouse bioassay is thus recognized as essential to the enhancement of shellfish toxicity monitoring and management of HABs. A viable alternative is the receptor binding assay with radiometric endpoint. The assay is based on the competition between a tritium-labelled saxitoxin and the saxitoxin in the sample on its sodium channel receptor sites. The methodology, facility and expertise are now available at the Philippine Nuclear Research Institute. In addition, a method for the analysis of saxitoxin using high performance liquid chromatography and its congeners is in place at the Marine Science Institute, University of the Philippines and the Bureau of Fisheries and Aquatic Resources of the Department of Agriculture.

# 5. COMPARATIVE RISK ASSESSMENT

## 5.1. Introduction

Based on the results of the Prospective Risk Assessment, 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 53-57. In these tables, lines represent general conditions in the bay, with their extent reflecting different RQ values for each contaminant, with the $RQ_{Geomean}$ as the lower end and the $RQ_{Max}$ as the upper end. Details regarding spatial and temporal distribution of RQs are in the Prospective RA section. Illustration of the average and worst-case (i.e., maximum MECs) conditions also serves to indicate uncertainty associated with the risk assessments. 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/PNEC value. Further, for most of the contaminants, uncertainty analysis was done 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 really exceeding the threshold, i.e., RQ>1, and the results of the analysis were presented in the pertinent sections of the Prospective Risk Assessment. The uncertainty analysis serves to give a probabilistic measure of the RQ really exceeding one and is particularly useful when the calculated RQ is at or near one.

For all stressors, the following data are presented: average MECs, maximum MECs, PNEC, average RQ, and maximum RQ. Average MECs were calculated as geometric mean MECs 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 PNEC used have already been presented and discussed in the Prospective Risk Assessment.

It should be noted that comparing risks across different contaminants on the basis of RQs has to be performed with caution for at least four reasons (MPP-EAS, 1999a):

1. Relationships between the differences in threshold values and exposure levels and ecological or human health effects are not likely to be linear and could take different forms for different contaminants;
2. The above-mentioned variations are likely to apply to different ecological entities (i.e., the same RQ for different contaminants could have different meanings);
3. The RQ analyses are based on chronic responses and do not take account of the episodic incidents at particular places; and
4. The relative priority of effects and hence of the agents causing them is not just a matter for science but also raises broader societal issues and perceptions. This is why comparative risk assessment often involves judgments from panels of experts and other stakeholders.

The RQ analysis, however, can provide some initial insights into relative risks. An RQ for any substance less than one suggest no immediate cause for concern. On the other hand, if the RQs are greater than 1,000, immediate risk reduction measures are suggested. Between these extremes, risks require more consideration, possibly with a more detailed or specific risk assessment and with increasing urgency as values increase in order-of-magnitude bands.

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

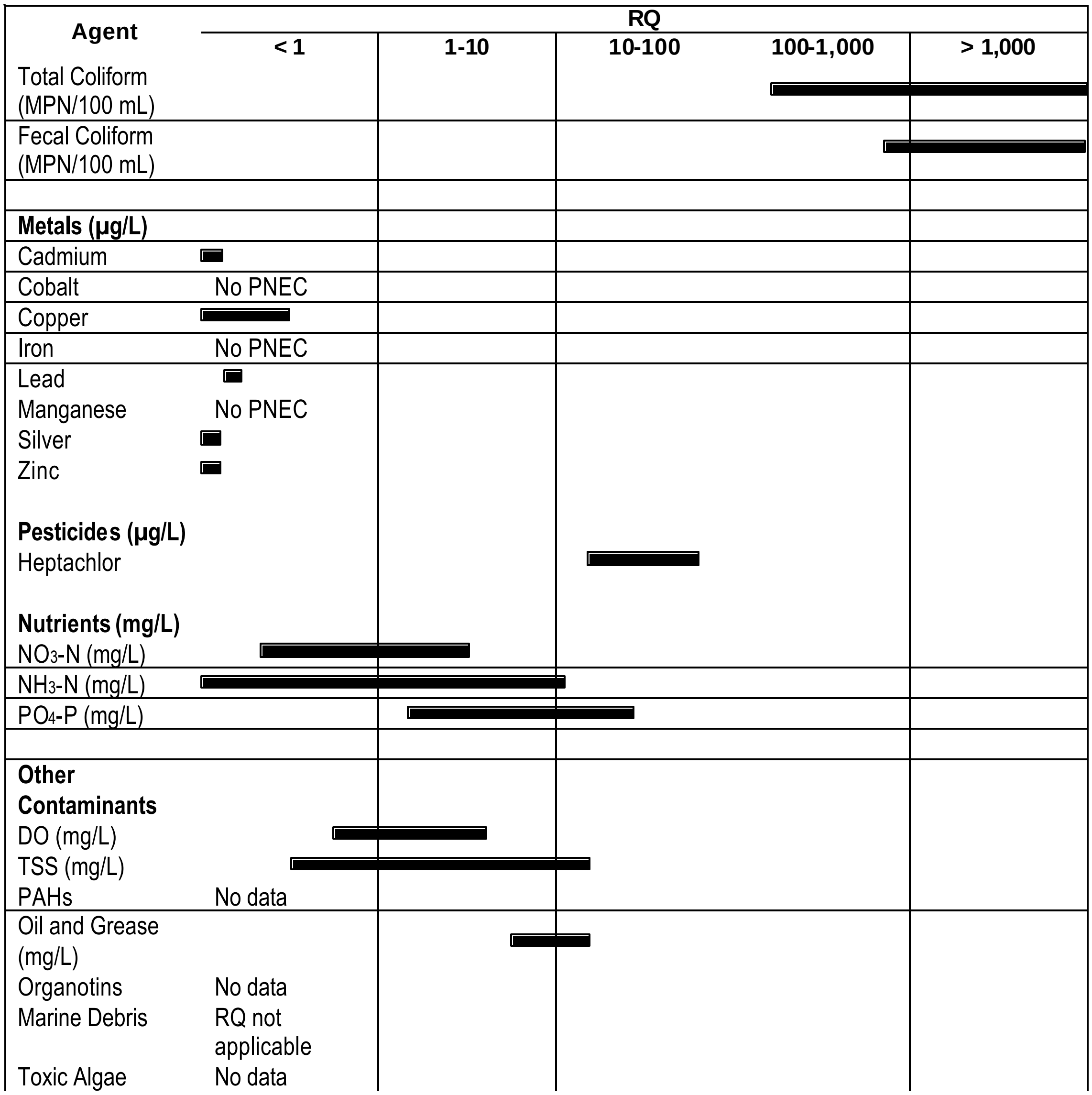
From Table 53 it is clear that of all contaminants for which water column data were available, only coliforms (both total and fecal), phosphate, heptachlor and oil and grease (2001 data) have $RQ_{Geomean}$ exceeding the critical threshold of one. However, in addition to these three contaminants, nitrate, ammonia, DO and TSS have $RQ_{Max}$ that exceed one. 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., Cb, Fe, and Mn).

Table 54 compares the range of RQs (from average to maximum) across contaminants in order of magnitude bands of RQ. From this table, it could be inferred that for the water column, risks to the ecosystem of Manila Bay associated with phosphate and coliforms are priority concerns. For nitrate, ammonia, DO and TSS, the maximum RQs exceeding one indicate localized risks from potential hot spots. This could be further looked into through any of the following: addition of sampling points taking into

**Table 53. Refined Risk Assessment Summary for the Water Column.**

| Agent | $MEC_{Geomean}$ | $MEC_{Max}$ | PNEC | $RQ_{Geomean}$ | $RQ_{Max}$ |
|---|---|---|---|---|---|
| Total Coliform (MPN/100 mL) | 735,413 | 16,000,000 | 5,000 | 147 | 3,200 |
| Fecal Coliform (MPN/100 mL) | 175,331 | 3,000,000 | 200 | 877 | 15,000 |
| **Metals (µg/L)** | | | | | |
| Cadmium | 0.03 | 0.33 | 9.3 | 0.003 | 0.035 |
| Cobalt | 23 | 24 | No data | | |
| Copper | 0.26 | 1.64 | 2.9 | 0.09 | 0.57 |
| Iron | 0.43 | 1.7 | No data | | |
| Lead | 0.6 | 0.8 | 5.6 | 0.11 | 0.14 |
| Manganese | 0.5 | 0.6 | No data | | |
| Silver | 0.04 | 0.05 | 2.3 | 0.02 | 0.02 |
| Zinc | 0.78 | 8.25 | 55 | 0.01 | 0.15 |
| **Pesticides (µg/L)** | | | | | |
| Heptachlor | 0.066 (min) | 0.2820 | 0.0035 | 18.9 | 80.6 |
| Other pesticides | < detection limits | | | | |
| **Nutrients (mg/L)** | | | | | |
| $NO_3$-N (mg/L) | 0.027 | 0.387 | 0.06 | 0.4 | 6 |
| $NH_3$-N (mg/L) | 0.003 | 0.779 | 0.07 | 0.04 | 11 |
| $PO_4$-P (mg/L) | 0.029 | 0.714 | 0.015 | 1.93 | 47.60 |
| | | | | | |
| **Other Contaminants** | | | | | |
| DO (mg/L) | 5.78 | 0.9 (min) | 5.0 | 0.87 | 5.6 |
| TSS (mg/L) | 23.32 | 1,048 | 50 | 0.5 | 21 |
| PAHs | No data | | | | |
| Oil and Grease (mg/L) | 1.399 (1985)<br>25.55 (2001) | 16.55 (1985)<br>54.26 (2001) | 3<br>3 | 0.5 (1985)<br>8.52 (2001) | 6 (1985)<br>18.09 (2001) |
| Organotins | No data | | | | |
| Marine Debris | RQ not applicable | | | | |
| Toxic Algae | No data | | | | |

**Table 54. Comparative (Ecological) Risk Assessment for the Water Column Based on Average to Worst-case RQs ($RQ_{Geomean}$ to $RQ_{Max}$).**




consideration land-based and other sources, and increasing the frequency of sampling, as noted in the recommendations on the need to establish monitoring programs.

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

From Table 55, it could be inferred that of all contaminants for which sediment data were available, the heavy metals Hg and Cu have $RQ_{Geomean}$ exceeding the critical threshold of one using the HK ISQV as PNEC. However, in terms of $RQ_{Max}$, all of the heavy metals for which data are available exceeded the critical threshold of one. Mercury had the highest $RQ_{Max}$ value among the heavy metals and for that matter, among the contaminants in sediment for which data are available. In addition to the heavy metals, total PAHs and dibenzo(a.h)anthracene as well as have maximum RQs equal to or above one. Very limited data, mostly less than detection limits, were available for pesticides in sediment. Criteria values were lacking for several of the heavy metals, particularly, Cu, Fe and Mn, as well as for most of the pesticides.

Table 56 compares the range of RQs (from average to maximum) across sediment-associated contaminants in order of magnitude bands of RQ. For sediment, risks to the ecology of Manila Bay associated with heavy metals, particularly, Hg and Cu are priority concerns. Of secondary importance are Pb, Cr, Zn, Cd and Ni among the heavy metals because their $RQ_{Max}$ exceeded one, indicating localized risks or hotspots. In addition, dibenzo(a,h)anthracene which is carcinogenic and total PAHs have maximum RQs also equal to or exceeding one, again indicating localized risks at possible hot spot areas.

**Table 55. Refined Risk Assessment Summary for Sediment.**

| Agent | $MEC_{Geomean}$ | $MEC_{Max}$ | PNEC | $RQ_{Geomean}$ | $RQ_{Max}$ |
|---|---|---|---|---|---|
| **Metals (mg/kg)** | | | | | |
| Cadmium | 0.04 | 2.55 | 1.5 | 0.03 | 1.7 |
| Chromium | 30.08 | 153.97 | 80 | 0.38 | 1.92 |
| Cobalt | 17.20 | 38.31 | No data | | |
| Copper | 110.84 | 410.92 | 65 | 1.7 | 6.32 |
| Lead | 23.85 | 264.05 | 75 | 0.32 | 3.52 |
| Mercury | 0.36 | 3.60 | 0.28 | 1.28 | 12.86 |
| Nickel | 24.34 | 59.93 | 40 | 0.61 | 1.50 |
| Zinc | 173.27 | 1465.01 | 200 | 0.87 | 7.32 |
| **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 | 0.02 | 0.064 | 0.0634 | 0.3 | 1.0 |
| Total PAH | 0.713 | 7.18 | 4.022 | 0.18 | 1.784 |
| | | | | | |
| **Pesticides (µg/g)** | | | | | |
| Aldrin | < 0.002 | | No data | | |
| Alpha-BHC | < 0.002 | | No data | | |
| Beta-BHC | < 0.002 | | No data | | |
| Delta-BHC | < 0.002 | | No data | | |
| Gamma-BHC | < 0.002 | | No data | | |
| 4,4-DD | < 0.010 | | No data | | |
| 4,4'-DDE | < 0.004 | | 0.0022 | < 1.8 | |
| 4,4'-DDT | < 0.010 | | 0.00158 | < 5.7 | |
| Dieldrin | < 0.004 | | No data | | |
| Endosulfan I | < 0.004 | | No data | | |
| Endosulfan II | < 0.004 | | No data | | |
| Endosulfan Sulphate | < 0.010 | | No data | | |
| Endrin | < 0.004 | | No data | | |
| Heptachlor | < 0.002 | | No data | | |
| Heptachlor Epoxide | < 0.002 | | | | |
| Methoxychlor | < 0.010 | | | | |

**Table 56. Comparative (Ecological) Risk Assessment for Sediment Based on Average to Worst-case RQs ($RQ_{Geomean}$ to $RQ_{Max}$).**

| Agent | RQ < 1 | RQ 1-10 | RQ 10-100 | RQ 100-1,000 | RQ > 1,000 |
|---|---|---|---|---|---|
| **Metals (mg/kg)** | | | | | |
| Cadmium | ▬ | ▬ | | | |
| Chromium | ▬ | ▬ | | | |
| Cobalt | No PNEC | | | | |
| Copper | | ▬ | | | |
| Lead | ▬ | ▬ | | | |
| Mercury | | ▬ | ▬ | | |
| Nickel | ▬ | ▬ | | | |
| Zinc | ▬ | ▬ | | | |
| **Carcinogenic PAHs (µg/kg)** | | | | | |
| Benzo(a)pyrene | ▬ | | | | |
| Chrysene | ▬ | | | | |
| Dibenzo(a,h) anthracene | ▬ | ▬ | | | |
| Total PAH | ▬ | ▬ | | | |
| **Other organics** | No MECs | | | | |
| **Pesticides (µg/g)** | | | | | |
| Aldrin | No PNEC | | | | |
| 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 | No PNEC | | | | |
| Endosulfan I | No PNEC | | | | |
| Endosulfan II | No PNEC | | | | |
| Endosulfan Sulphate | No PNEC | | | | |
| Endrin | No PNEC | | | | |
| Heptachlor | No PNEC | | | | |
| Heptachlor Epoxide | No PNEC | | | | |
| Methoxychlor | No PNEC | | | | |

## 5.4. COMPARATIVE ASSESSMENT OF RISKS TO HUMAN HEALTH

### 5.4.1. RQ-based Risk Assessment

Results of the refined risk assessment showed that pelagic fish is contaminated with mercury ($RQ_{Geomean} > 1$). In terms of worst-case RQ or $RQ_{Max}$, Pb in both pelagic and demersal fish and in shellfish including bivalves; Cd, Cu, Hg and Zn in shellfish; endosulfan sulfate, endosulfan I and endrin in shellfish; and aldrin and heptachlor in fish exceeded one.

The RQ approach itself is somewhat simplistic in defining actual risks to human health from environmental contaminants due to the following reasons: (1) the PNEC are derived for a single chemical in isolation and therefore may not be sensitive to the effect of synergy of various contaminants; (2) the PNEC is usually calculated from data of specific target population that may not be relevant to the exposed system or population; and (3) MECs or even PNECs are presumed to be time invariant, but in reality MECs can change through time in relation to both seasonal or diurnal shifts and PNECs may also change through time with changes in age structure and composition of target population.

Despite these intrinsic limitations of the RQ approach, it is considered adequate in assessing ecological risks. It is also useful as a screening tool to identify areas of concern to human health but ideally needs to be supplemented with other approaches considering that the state of human health is a function of many variables. Another factor among others is that a potential and immediate health effect of various environmental pollutants varies significantly in terms of toxicity and ability to bio-accumulate in the human body. Although it can be assumed that these factors are taken into consideration in establishing the TDIs for contaminants, the TDIs were adopted from the USFDA for a Caucasian population and the data that served as basis for these standards were not available to the TWG team on Human Health. For conservatism, the TWG's Human Health Team thus agreed to develop an initial set of criteria (which can be further refined) to evaluate and prioritize environmental contaminants qualitatively in the refined risk assessment. The criteria is composed initially of the following parameters: (1) the calculated RQ; (2) bioaccumulation potential; and (3) toxicity level (e.g., $LD_{50}$) of the environmental/tissue contaminant.

Box 2 shows the rating scale assigned to each criterion.

**Box 2. Rating Scale for Human Health Risk.**

**1. For Risk Quotient (RQ)**

| | | |
|---|---|---|
| <1–0 | Minimal Health Effect | 0 |
| 1-10 | Significant Health Effect | 1 |
| 10-100 | Significant Health Effect | 2 |
| 100-1000 | Significant Health Effect | 3 |
| >1000 | Significant Health Effect | 4 |

**2. For Bioaccumulation Potential (BP)**

| | | |
|---|---|---|
| 0 | No BP Potential | 0 |
| 0-25% | Slight | 1 |
| 25-50% | Moderate | 2 |
| 50-75% | High | 3 |
| >75% | Very High | 4 |

**3. Toxicity Level (e.g., $LD_{50}$, Potential for Liver Damage, Infection)**

| | |
|---|---|
| Negligible Toxicity | 0 |
| Slight | 1 |
| Moderate | 2 |
| High | 3 |
| Very High | 4 |

The different contaminants that were found in tissues (fish and shellfish) and therefore can affect humans through the ingestion pathway were scored according to the above criteria. The total points were added up and the higher the total points, the higher the priority rating for risk management. Priority rating is from one to four, wherein one corresponds to the highest priority. As suggested by Table 57, if the risks to the agents were scored based on the calculated RQs for fish and shellfish, bioaccumulation potential and toxicity level, the priority agents for risk management to prevent adverse health effects are: Hg and Pb among the heavy metals; fecal coliform; and aldrin and heptachlor among the pesticides. In the next order of priority is Cd among the heavy metals and endosulfan sulfate, endosulfan I and endrin among the pesticides.

### 5.4.2. Exposure Dosage (Estimated Daily Intake) Calculation

Among the five heavy metals (Cu, Zn, Cd, Hg, and Pb) present in fish samples, Hg and Pb pose potential risk to human health. The maximum RQ values for mercury and lead in most pelagic fish species are greater than one. Zinc is an essential mineral of the body, so RQ of more than one may not be a cause of concern, but the consumption of greater amounts in extended period of time will increase the risk of marginal toxicity. The doses of heavy metals actually received on a daily basis by coastal populations around Manila Bay through the ingestion pathway were thus calculated to provide information in addition to the RQs as discussed in Section 4.4.

#### 5.4.2.1. Fish tissue

##### 5.4.2.1.1. Mercury (Hg)

Fish absorbs methyl mercury from water as it passes over their gills and as they feed on aquatic organisms. Larger predator fish are exposed to higher levels of methyl mercury from their prey.

In the study conducted in 1997 (Prudente *et al.*), Hg was found in fish samples collected from Manila Bay at levels ranging from 0.049 μg/g to as high as 1.39 μg/g. With a consumption rate of 80 grams per day for an average person (60 kg) (FNRI, 1993), it was estimated that a person from

**Table 57. Priority Rating of Contaminants in Manila Bay in Terms of Human Health Risks.**

| Agent | Risk Quotient (RQ) | | Bioaccumulation Potential | Toxicity Level | Total | Priority Rating |
|---|---|---|---|---|---|---|
| | Fish | Shellfish | | | | |
| **Metals** | | | | | | |
| Copper | 1 | 1 | 1 | 2 | 5 | 3 |
| Lead | 1 | 1 | 4 | 4 | 10 | 1 |
| Cadmium | 0 | 1 | 4 | 4 | 9 | 2 |
| Zinc | 1 | 1 | 0 | 0 | 2 | 4 |
| Mercury | 1 | 1 | 4 | 4 | 10 | 1 |
| **Coliform** | 4 | 4 | 0 | 2 | 10 | 1 |
| **PAH** | no data | no data | 4 | 4 | | |
| **Pesticides** | | | | | | |
| Aldrin | 2 | | 4 | 4 | 10 | 1 |
| DDE | 0 | | 4 | 4 | 8 | 3 |
| DDT | 0 | | 4 | 4 | 8 | 3 |
| Endosulfan I | 0 | 1 | 4 | 4 | 9 | 2 |
| Endosulfan II | 0 | | 4 | 4 | 8 | 3 |
| Endosulfan Sulfate | 0 | 1 | 4 | 4 | 9 | 2 |
| Endrin | 0 | 1 | 4 | 4 | 9 | 2 |
| Heptachlor | 2 | | 4 | 4 | 10 | 1 |

Metro Manila and Southern Luzon is exposed to methyl mercury ranging from 0.065 to 0.27 µg/kg-BW/day from consumption of demersal fish and higher values, i.e., 0.164 to 1.853 µg/kg-BW/day from consumption of pelagic fish. The maximum RQ values of Hg (15.7 for lactating mothers 14 to 19 years old) were found to be highest among the five heavy metals studied.

Using the same heavy metal data and a consumption rate of 69 grams per day for an average Filipino living in Central Luzon (FNRI, 1993), it was estimated that exposure to Hg ranges from 0.056 to 1.6 µg/kg BW/day. Table 58 shows the calculated exposure dose of Hg received by the general population through fish ingestion.

Based on physiological status of the individual, maximum RQ values were highest among the 14 to 19 year old lactating women, 30 to 39 year old pregnant women and children four to six years old. The maximum RQ values for mercury ranged from about 1 to 11.

For lactating mothers (14 to 19 years old), the maximum intake of Hg is about 4.2 µg/kg-BW/day while for the 30 to 39 years old pregnant women, 3 µg/kg-BW/day . With regard to Filipino children, based on the average mean weight shown in Table 59, children of three to four years old have the highest uptake of Hg of about 6.5 µg/kg-BW/day through consumption of pelagic fish. Children are considered as the more vulnerable group to mercury exposure. Table 58 shows the estimated amount of Hg taken through fish consumption.

#### 5.4.2.1.2. Lead (Pb)

Lead was the second heavy metal found to be of relatively significant levels in various fish samples. The maximum RQ values were obtained for the crevalle species (pelagic) and mullet species (demersal). Fish samples such as sardine (*Sardinella leiogaster*), crevalle (*Selroides leptolepis*) and Sardinella sp. (*Sardinella punctatus*) have tissue levels of lead of 0.27 µg/g, 0.3 µg/g and 0.24 µg/g, respectively.

**Table 58. Calculated Exposure Dose to Heavy Metals from Consumption of Fish.**

| | Exposure Dose (mg/kg/day) | | | |
|---|---|---|---|---|
| **Metals** | **Metro Manila/Southern Tagalog** | | **Central Luzon** | |
| Demersal | **Max** | **Min** | **Max** | **Min** |
| Hg | 0.27 | 0.065 | 0.235 | 0.056 |
| Pb | 0.401 | 0.05 | 0.346 | 0.043 |
| Cd | 0.095 | 0.008 | 0.082 | 0.007 |
| Cu | 4.61 | 1.48 | 3.979 | 1.27 |
| Zn | 165.33 | 56.4 | 142.6 | 48.6 |
| | | | | |
| Pelagic | | | | |
| Hg | 1.85 | 0.164 | 1.598 | 0.14 |
| Pb | 0.394 | 0.077 | 0.34 | 0.066 |
| Cd | 0.090 | 0.003 | 0.078 | 0.003 |
| Cu | 7.267 | 2.506 | 6.26 | 2.16 |
| Zn | 150.67 | 52 | 129.95 | 44.85 |

**Table 59. Mean Weight of Filipino Children.**

| Age Group | Mean Weight (kg) |
|---|---|
| 1 – < 2 | 10 |
| 2 – < 3 | 12 |
| 3 – < 4 | 14 |
| 4 – < 6 | 18 |

For demersal fish samples, lead content in the mullet fish was the highest with 0.3 μg/g.

Based on the physiological status of the individual, the highest $RQ_{Max}$ values were noted among the 14 to 19 year old lactating mothers, 30 to 39 year old pregnant women, and children four to six years old.

Using the same formula for calculating the exposure dose of contaminants (Section 4.4.2), the amount of Pb taken by the general population through consumption of demersal fish ranges from 0.05 to 0.4 μg/kg-BW/day for Metro Manila/ Southern Tagalog and 0.04 to 0.35 μg/kg-BW/day for Central Luzon. The amount of Pb ingested in pelagic fish ranges from 0.08 to 0.4 μg/kg-BW/ day for Metro Manila and Southern Tagalog and about 0.07 to 0.34 μg/kg-BW/day for Central Luzon. Table 60a shows the respective amounts of Pb taken by different groups through consumption of pelagic fish.

For lactating mothers, the age group of 14 to 19 years old was among the most exposed to Pb through consumption of pelagic fish. The maximum taken by this group is about 0.9 μg/kg-BW/day. On the other hand, pregnant women of ages 30 to 39 years old were estimated to have a maximum intake of 0.6 μg/kg-BW/day. It should be noted that children are among the most vulnerable to this contaminant. For children one to six years old, uptake of Pb may impair brain development. Table 60a shows that the amount of Pb ingested by children through consumption of pelagic fish ranges from 0.2 to 1 μg/kg-BW/ day.

The same trend was also observed in the exposure dose calculation for demersal fish. Table 60b shows the calculated amount of contaminants taken by different groups.

#### 5.4.2.2 Shellfish tissue

The data on shellfish was based on the Pasig River Rehabilitation Project reports (PRRP, 1999). Among the heavy metals studied, Zn and Cu were the most commonly found contaminants; however, Pb, Hg and Cd were also detected in shellfish although in comparatively less amounts. Based on the initial set of criteria developed by the TWG team on Human Health, the three contaminants (Pb, Hg and Cd) have the greater potential to cause adverse health effects to the communities studied.

##### 5.4.2.2.1. Zinc (Zn)

Zinc is the heavy metal most commonly found in shellfish samples taken from Metro Manila with concentrations ranging from 37,000 – 1,590,000 μg/ kg dry. With a consumption rate of 29.5 grams per day for Metro Manila, the calculated exposure dose ranges from 18-782 μg/kg-BW/day (Table 61). The computed worst-case risk quotient ($RQ_{Max}$) is 9.4.

For Central Luzon, Zn also had the highest concentration in shellfish samples ranging from 37,000–1,590,000 mg/kg dry. Based on a consumption rate of 18 grams per day, the calculated exposure dose ranges from 11 – 477 mg/ kg-BW/day. The computed $RQ_{Max}$ is 5.7 but the $RQ_{Geomean}$ is less than 1. Shellfish samples from Southern Luzon showed a similar trend.

##### 5.4.2.2.2. Lead (Pb)

Lead was also found in various shellfish samples taken from different parts of manila Bay. The shellfish samples showed tissue levels ranging from 4.99–3,600 μg/kg dry (Table 61). With a consumption rate of 29.5 grams/day in Metro Manila, it was calculated that the exposure dose to lead from shellfish ranges from 0.002 – 1.77 μg/kg-BW/day. $RQ_{Max}$ was computed to be 7.08 for the

**Table 60a. Calculated Exposure Dose to Heavy Metals from Consumption of Pelagic Fish.**

| | Exposure Dose (mg/kg/day) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Cu | | Zn | | Cd | | Hg | | Pb | |
| | Max | Min | Max | Min | Max | Min | Max | Min | Max | Min |
| Lactating Mother | | | | | | | | | | |
| All age | 11.72 | 4.0 | 242.95 | 83.85 | 0.14 | 0.0053 | 2.99 | 0.26 | 0.64 | 0.123 |
| 14 – 19 | 16.44 | 5.7 | 340.88 | 117.65 | 0.20 | 0.0074 | 4.19 | 0.37 | 0.89 | 0.173 |
| 20 – 29 | 11.08 | 3.8 | 229.77 | 79.30 | 0.14 | 0.0050 | 2.83 | 0.25 | 0.60 | 0.117 |
| 30 – 39 | 12.17 | 4.2 | 252.37 | 87.10 | 0.15 | 0.0055 | 3.10 | 0.27 | 0.66 | 0.128 |
| 40 – 50 | 10.26 | 3.5 | 212.82 | 73.45 | 0.13 | 0.0046 | 2.62 | 0.23 | 0.56 | 0.108 |
| Pregnant Women | | | | | | | | | | |
| All age | 11.08 | 3.8 | 229.77 | 79.30 | 0.14 | 0.0050 | 2.83 | 0.25 | 0.60 | 0.117 |
| 14 – 19 | 8.18 | 2.8 | 169.50 | 58.50 | 0.10 | 0.0037 | 2.09 | 0.18 | 0.44 | 0.086 |
| 20 – 29 | 10.99 | 3.8 | 227.88 | 78.65 | 0.14 | 0.0049 | 2.80 | 0.25 | 0.60 | 0.116 |
| 30 – 39 | 11.81 | 4.1 | 244.83 | 84.50 | 0.15 | 0.0053 | 3.01 | 0.27 | 0.64 | 0.124 |
| 40 – 50 | 9.27 | 3.2 | 192.10 | 66.30 | 0.11 | 0.0042 | 2.36 | 0.21 | 0.50 | 0.098 |
| Children | | | | | | | | | | |
| 1 - 2 yrs | 26.71 | 9.2 | 553.70 | 191.10 | 0.33 | 0.0120 | 6.81 | 0.60 | 1.45 | 0.281 |
| 2 - 3 yrs | 27.25 | 9.4 | 565.00 | 195.00 | 0.34 | 0.0120 | 6.95 | 0.62 | 1.48 | 0.287 |
| 3 - 4 yrs | 25.3 | 8.7 | 524.64 | 181.07 | 0.31 | 0.0110 | 6.45 | 0.57 | 1.37 | 0.267 |
| 4 - 6 yrs | 21.19 | 7.3 | 439.44 | 151.67 | 0.26 | 0.0095 | 5.41 | 0.48 | 1.15 | 0.223 |

**Table 60b. Calculated Exposure Dose to Heavy Metals from Consumption of Demersal Fish.**

| | Exposure Dose (mg/kg/day) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Copper | | Zinc | | Cadmium | | Mercury | | Lead | |
| | Max | Min | Max | Min | Max | Min | Max | Min | Max | Min |
| Lactating Mother | | | | | | | | | | |
| All age | 7.44 | 2.4 | 266.6 | 90.95 | 0.15 | 0.013 | 0.44 | 0.10 | 0.65 | 0.081 |
| 14 – 19 | 10.44 | 3.3 | 374.07 | 127.61 | 0.21 | 0.018 | 0.62 | 0.15 | 0.91 | 0.113 |
| 20 – 29 | 7.04 | 2.3 | 252.13 | 86.01 | 0.14 | 0.012 | 0.41 | 0.10 | 0.61 | 0.076 |
| 30 – 39 | 7.73 | 2.48 | 276.93 | 94.47 | 0.16 | 0.014 | 0.46 | 0.11 | 0.67 | 0.084 |
| 40 – 50 | 6.52 | 2.09 | 233.53 | 79.67 | 0.13 | 0.011 | 0.38 | 0.09 | 0.57 | 0.071 |
| Pregnant Women | | | | | | | | | | |
| All age | 7.04 | 2.3 | 252.13 | 86.01 | 0.14 | 0.012 | 0.41 | 0.10 | 0.61 | 0.076 |
| 14 – 19 | 5.19 | 1.7 | 186.00 | 63.45 | 0.11 | 0.009 | 0.31 | 0.07 | 0.45 | 0.056 |
| 20 – 29 | 6.98 | 2.2 | 250.07 | 85.31 | 0.14 | 0.012 | 0.41 | 0.10 | 0.61 | 0.076 |
| 30 – 39 | 7.50 | 2.41 | 268.67 | 91.65 | 0.15 | 0.013 | 0.44 | 0.11 | 0.65 | 0.081 |
| 40 – 50 | 5.88 | 1.9 | 210.8 | 71.91 | 0.12 | 0.010 | 0.35 | 0.08 | 0.51 | 0.064 |
| Children | | | | | | | | | | |
| 1 - 2 yrs | 16.95 | 5.4 | 607.60 | 207.27 | 0.35 | 0.03 | 1.00 | 0.24 | 1.47 | 0.184 |
| 2 - 3 yrs | 17.30 | 5.6 | 620.00 | 211.50 | 0.36 | 0.03 | 1.02 | 0.24 | 1.51 | 0.188 |
| 3 - 4 yrs | 16.06 | 5.2 | 575.71 | 196.39 | 0.33 | 0.03 | 0.95 | 0.23 | 1.40 | 0.174 |
| 4 - 6 yrs | 13.46 | 4.3 | 482.22 | 164.50 | 0.28 | 0.02 | 0.79 | 0.19 | 1.17 | 0.146 |

seven year to adult age group but $RQ_{Geomean}$ was less than one, suggesting localized risks.

Using the same heavy metal data in shellfish and a consumption rate of 18 grams per day in Central Luzon, exposure dose was calculated ranging from 0.0015 – 1.08 µg/kg-BW/day (Table 61). The calculated worst-case RQ ($RQ_{Max}$) was 4.32 for the seven year to adult age group, but the $RQ_{Geomean}$ was less than one.

For Southern Luzon,using the same data set and a consumption rate of 16 grams per day, the calculated exposure dose ranges from 0.0001 to 0.96 µg/kg-BW/day (Table 61). The computed worst-case risk quotient ($RQ_{Max}$) was 3.84 for the seven year to adult age group but as in the case with Metro Manila and Central Luzon, the $RQ_{Geomean}$ was below one.

#### 5.4.2.2.3. Mercury (Hg)

Mercury is also one of the heavy metals found in various shellfish samples. Shellfish samples showed mercury in tissues ranging from 0.49 to 2,700 µg/kg dry. With a consumption rate of 29.5 grams per day for Metro Manila, the exposure dose was calculated ranging from $2.4 \times 10^{-4}$ to 1.33 µg/kg-BW/day (Table 61). The $RQ_{Max}$ was 4.98 but the $RQ_{Geomean}$ was also less than one.

With a consumption rate of 16 grams per day for Central Luzon, the calculated exposure dose ranges from $1.5 \times 10^{-4}$ to 0.81 µg/kg-BW dry. (Table 61). The maximum risk quotient was 3.04 but the $RQ_{Geomean}$ was also less than one. Shellfish samples taken from Southern Luzon likewise showed a similar trend.

### 5.5. HAZARDOUS/TOXIC EFFECTS OF HEAVY METALS

#### 5.5.1. Toxic Effects of Mercury (Hg)

Effects of toxic exposure to Hg are cumulative in nature, although some symptoms may manifest acutely if exposed to toxic doses. The type of symptoms reflect the degree of exposure. Paresthesia (numbness and tingling sensations around the lips, finger and toes) usually is the first symptom. A stumbling gait and difficulty in articulating words is the next progressive symptom, along with a constriction of the visual fields, ultimately leading to tunnel vision and impaired hearing. Generalized muscle weakness, fatigue, headache, irritability, and inability to concentrate often occur. In severe cases, tremors or jerks are present. These neurological problems frequently lead to coma and death. Ingestion of a toxic dose of mercuric chloride can soon after cause severe nausea, vomiting, diarrhea and abdominal pain, culminating in cardiovascular collapse. Azotemia and anuria develop within few hours to three days. Death may occur within 6 to 23 days post ingestion. Child-bearing women and nursing mothers are critical groups of concern since mercury can cross the placenta and affect unborn children and may damage the reproductive organs.

**Table 61. Calculated Exposure Dose to Heavy Metals from Consumption of Shellfish.**

| Metals | MEL (µg/dry-kg) | | Exposure Dose Calculation (µg/kg/day) Metro Manila | | Central Luzon | | Southern Luzon | |
|---|---|---|---|---|---|---|---|---|
| | Max | Min | Max | Min | Max | Min | Max | Min |
| Cadmium | 2,200 | 3.90 | 1.082 | 0.0019 | 0.66 | 0.0012 | 0.587 | 0.001 |
| Copper | 187,000 | 6,200 | 91.942 | 3.05 | 56.10 | 1.86 | 49.867 | 1.653 |
| Lead | 3,600 | 4.90 | 1.77 | 0.0025 | 1.08 | 0.0015 | 0.96 | 0.0013 |
| Mercury | 2,700 | 0.49 | 1.328 | 0.0002 | 0.81 | 0.0001 | 0.72 | 0.0001 |
| Zinc | 1,590,000 | 37,000 | 781.75 | 18.19 | 477 | 11.1 | 424 | 9.867 |

### 5.5.2. Toxic Effects of Lead (Pb)

Symptoms from acute toxicity of Pb are rare. Most common are manifestations of sub-acute and chronic exposure. At low levels of exposure, patients may present with constitutional symptoms such as fatigue, malaise, irritability, anorexia, insomnia and weight loss, arthralgias and myalgias.

For children, early signs of encephalopathy include irritability, lethargy, ataxia, bizarre behavior, apathy and memory loss. The sequelae of Pb encephalopathy, may be severe and can include cortical atrophy, hydrocephalus, and convulsive seizures.

More commonly, lead exposure in children manifests as decreased intelligence. Lead exerts a direct effect on learning and also produces behavioral impairments. There is a note of change in reaction time, postural disequilibrium, deficits in visual-motor function, auditory acuity, perceptual integration, and verbal abstraction. Attention deficits may be due to increased distractibility or preservative behavior. Acquisition behavior and difficult discriminations are also affected.

### 5.5.3. Toxic Effects of Zinc (Zn)

Zinc is required for growth and development of every animal species. It is absorbed primarily in the duodenum and binds to all proteins in the plasma, however, it is loosely bound to albumin and this is important for transport to and from tissues.

The taste threshold for a soluble salt of Zn in water is 15-ppm Zn, whereas 40 ppm has a very definite taste. A dose of 225 to 450 mg Zn has an emetic effect in an adult man. Dehydration, electrolyte imbalance, stomach pain, lethargy, dizziness, muscular non-coordination and renal failure characterize acute toxicity of Zn.

# 6. CONCLUSIONS

## 6.1 Retrospective Risk Assessment

### 6.1.1. Resources

For resources, a clear evidence of significant decline in quantity and quality was firmly established for fisheries and shellfisheries. The adverse ecological, economic, and social consequences of the observed decline in these 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.

Manifestations of the decline in quantity of fisheries include: (1) decline in trawl CPUE (kg/hr) from 46 to 13.8 during the period 1947-1959 to 14 to 10 (1986-1993); (2) decline in demersal biomass from 4.61 mt/km$^2$ or 8,290 tons in 1947 to about 10 percent, i.e., 0.47 mt/km$^2$ or 840 tons in 1993; (3) exploitation of demersal fisheries far beyond the Bay's MSY; (4) increase in number of fishers per km of coastline by 360 percent, i.e., from 70 in 1987 to 253 in 1993; (5) increase in number of boats per km coastline by 140 percent, i.e., from 74 in 1980 to 105 in 1993.

Manifestations of the deterioration in quality of fisheries include: (1) change in trawl catch composition from economically valuable to less valuable species; (2) decrease in the relative abundance of finfish and increase in invertebrates of the demersal fisheries; (3) increase in the relative abundance of pelagic species in the demersal trawl catch; (4) disappearance/near-absence of some species (e.g. lizard fish and flat fish); (5) disappearance of larger individuals; and (6) dominance of immature individuals.

For shellfisheries, unstable production of commercially valuable mussels and oysters, disappearance of the windowpane oyster and contamination of shellfish, particularly with fecal coliforms, are other manifestations of poor management of shellfisheries with consequent deterioration in quality.

The identified primary agents for the significant decline in fisheries and shellfisheries were overcollection as a result of growth and recruitment overfishing 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 DO in the water column indicating increased oxygen demand in 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 organisms. 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.

Socio-economic considerations can also have a bearing on the density of fish resources in Manila Bay. As stressed in the implementing rules and policies for management and conservation of fisheries in the Philippines, all users of municipal waters are authorized to operate within about ten (10.1) to fifteen (15) kilometers from the shoreline. The number of municipal fishermen compared to commercial fishermen is higher such that most

**Table 62. Summary of Evidence of Decline, Areal Extent, and the Consequences of Decline on 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 - refers only to the market value of the resource*

fishermen are concentrated in the zone between 4 to 20 km from the shore. Close competition for higher yield in the fishing areas will result in over-fishing and lead to decline in fish resources. Enforcement of laws and regulations is, however, costly. This is the problem encountered for management of commercial and municipal fishing in the Philippines, especially in the case of tuna fishing (Arce, 1988).

Nitrogen loading from aquaculture farms is not only toxic to the fish but also stimulates eutrophication. Nutrient loading from fish cages enters marine waters in the form of nitrate, ammonia, total organic nitrogen or total nitrogen. Intensive aquaculture practices pose further damaging effects to fishery resources with the use of chemical and biological products to solve the self-polluting characteristics of intensive ponds.

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. However, changes in species composition or a bloom in certain species may be indicative of eutrophication or harmful algal bloom commonly referred to as red tide.

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

Table 62 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 seaweed, 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 seaweed was considered moderate because this was based on the market value of the seaweed and did not consider the loss of ecological functions and contribution to decline in fisheries.

### 6.1.2. Habitats

For habitats, clear evidence of decline was established only for mangroves. Mangrove areas have declined from an estimated 54,000 ha in 1890 to around 2,000 ha in 1990 to about 794 ha at present. 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 is also one cause of decline. Other possible factors 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 at 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. Destruction of mangrove forests in Manila Bay have led to 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.

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. This destruction of mangroves and coral reefs 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 63 summarizes 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

**Table 63. Summary of Evidence of Decline, Areal Extent, and the Consequences of Decline on 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 - refers only to the market value of the habitat* the resources, the economic consequences of decline refer only to the market values of the particular habitat.

### 6.1.3. Physical Changes

Changes in physical features such as shoreline and bathymetry were examined insofar as they affect habitats and resources. Changes in the position of the shoreline along the coast of Manila are clearly man-induced as indicated by the presence of seawalls, breakers, and reclaimed areas for real estate development. The seaward movement of land best indicates the decline in the surface area of Manila Bay. This is caused mainly through such activities as reclamation and conversion of mangrove and mudflat areas into fishponds. Other factors include such processes as erosion and siltation. These factors have decreased the total surface area of the bay

The shallowing and sediment deposition in the bay is attributed to erosional forces along the bay's coastline which are mostly man-induced. The probable causes include the disposal of dredged materials into the bay, increase in agricultural and aquacultural activities along the coast of the bay plus the continuous denudation of its watershed areas which in turn, contributed significantly to the decline of marine resources in the bay and the worsening condition of its bottom topography and shallowing depth.

The overall state of the resources and habitats in Manila Bay point to the urgent need for improved management of these resources, long-term planning and zonation that can ensure sustainable development, and stronger implementation of protective regulations and laws that can avert the inevitable consequences of over-exploitation and destruction of these valuable resources and habitats.

## 6.2. PROSPECTIVE RISK ASSESSMENT

### 6.2.1. Water Column

For the prospective risk assessment, the risks due to the following contaminants in the water column were evaluated: coliforms (total and fecal), heavy metals, pesticides, nutrients (nitrate, ammonia and phosphate), DO, TSS, oil and grease, oil spills, marine debris (solid wastes) and toxic algae.

The $RQ_{Geomean}$ exceeded one for coliforms (total and fecal), phosphate and heptachlor, indicating that these are the contaminants of priority concern. The $RQ_{Geomean}$ for oil and grease exceed one if based on the most recent data only (2001), signaling worsening conditions for oil and grease in the bay. The levels of Hg, Pb and Cu in the river mouths are relatively high.

Among the contaminants, the RQ values for coliforms are the highest. The calculated average $RQ_{Geomean}$ for fecal coliform increased dramatically from 73 in 1996 to 128 in 1998. On the other hand, $RQ_{Geomean}$ for total coliform decreased from 11 in 1996 to four in 1998, but severely escalated to 20 in the year 1999. In general, the $RQ_{Geomean}$ during wet season is higher than dry season for both fecal and total coliform. In terms of worst-case RQ or $RQ_{Max}$, a value as high as 15,000 was obtained for fecal coliform in Bacoor in 1999. People bathing in beaches along the eastern portion of Manila Bay have relatively greater risk of becoming affected in terms of skin itchiness, diarrhea, or worse, if the water is swallowed and the conditions have not improved. 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 end up in the bay, and to the sewage outfall in Manila Bay. Other sources include commercial and agricultural establishments, such as slaughterhouses, markets, livestock farms, hospitals, and urban and rural run-off.

All RQs for metals in water are well below one for the three PNEC values applied. The $RQ_{Max}$ exceeded one for Hg, Pb and Cu, based on samples obtained from the river mouths. When the more conservative US EPA criteria rather than the local DAO 34 criteria are applied as PNEC, the $RQ_{Geomean}$ for Hg was 24 and for Pb, 2.4 for water samples taken from the river mouths during two sampling periods. The highest concentrations of Cu and Pb were found in Cavite, Hg and Zn in Pampanga, and Cd in Metro Manila. These metal concentrations were higher than the concentrations inside the Bay, suggesting that the contribution of land-based human activities which lead to the release of metals which, in turn, are eventually transported into the Bay through the rivers, is a major source of metals in the Bay.

The results give an indication of the range of RQs that would be obtained if criteria values that differ in degree of protectiveness were used. The Philippine criteria (DAO 34) for these heavy metals in the water column need to be reviewed, considering that the Philippine criteria are at least an order of magnitude higher than the US EPA criteria for certain metals.

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

Among the 16 pesticides analyzed, the $RQ_{Geomean}$ exceeded one only for heptachlor using the marine chronic criteria from the USEPA. The $RQ_{Max}$ for heptachlor was high (80.57) while the lowest RQ also exceeded one (18.86), indicating relatively significant risk from heptachlor in Manila Bay waters.

For the nutrients, the worst-case RQs ($RQ_{Max}$) for nutrients (nitrates, ammonia, phosphate) are greater than one. The $RQ_{Geomean}$ values, however, are < 1 for nitrate and ammonia and > 1 for phosphate. $RQ_{Geomean}$ for phosphate exceeded 1 in most cases at surface, mid-depth and bottom layers of the water column. All the $RQ_{Geomean}$ calculated based on 1998 data were greater than one at all depths studied, indicating that the phosphate is a significant environmental stressor in Manila Bay. Phosphate is traceable to contributions from agricultural residuals, domestic sewage, and detergents.

The RQ approach could not be applied to assess the risks due to oil spills, marine debris and toxic algae. However, these are agents that can do significant harm to resources and habitats and require attention. Data on the extent of contamination from these agents were provided based on available data. There are no data available for organotins, but considering its effects on gastropods (imposex), some background information form the literature was provided.

These conclusions confirm and add to those arrived at during the initial risk assessment. The initial risk assessment identified phosphate as a contaminant of major concern. It also ascribed localized risks to oil and grease, nutrients (ammonia and nitrate) and some organochlorine pesticides (dieldrin and heptachlor)

### 6.2.2. Sediment

The contaminants analyzed in the sediments are heavy metals, pesticides and PAHs.

The $RQ_{Geomean}$ exceeded one for Cd, Pb and Zn when the shale values are applied while the $RQ_{Geomean}$ exceeded one for Cu and Hg using the HK ISQV as criteria.

The contaminants for which $RQ_{Max}$ exceeded one indicating localized or intermediate risks are: all heavy metals studied regardless whether the more conservative shale values or HK ISQV are used as PNECs since the sediment data included coastal Metro Manila sediment where the metal loads are high and, total PAH which is a summation of 18 individual PAHs and the carcinogenic dibenzo(a,h)anthracene (localized in one area only).

Heavy metals in this context refer to the total leachable metal concentrations which approximate the concentration of the mobile or potentally bioavailable metal phases hosted by the fine-grained sediments (i.e., particle size <2 ìm). Since the sediment data included coastal Metro Manila sediment where the metal loads are high, the $RQ_{Max}$ are greater than one for all metals with the exception of Ni, regardless whether the more conservative shale values or HK ISQV are used as PNECs. However, the $RQ_{Geomean}$ exceeded one only for Cd, Pb and Zn when the shale values are applied while the $RQ_{Geomean}$ exceeded one only for Cu and Hg with the HK ISQV.

The scenarios, however, change when only the sediments of coastal Metro Manila area, defined from the distribution patterns of Pb and Zn, are considered in the $RQ_{Geomean}$ calculation. Because of the extremely high concentrations of Pb and Zn in the sediments of coastal Metro Manila, the $RQ_{Geomean}$ calculated for the whole bay is enhanced by them, giving an erratic signal that the sediments of the whole bay maybe enriched in Pb and Zn, while, in fact, only the coastal Metro Manila area, i.e. about five percent of the total bay area, has sediments with high Pb and Zn loads. The $RQ_{Geomean}$ for Pb and Zn increased twofold of their whole bay $RQ_{Geomean}$ when calculated only for the coastal Metro Manila area. This reveals that the sediment-based RQ values, in order to be accurate in this case, should be interpreted with the lateral distribution patterns of the metals.

Sediment from the mouths of the Malabon-Navotas and the Parañaque Rivers have the highest MECs, certainly indicating that these rivers are point sources of metals for the Bay. Cd, Hg, Zn, Pb, and Ni are highest in the sediment taken from the mouth of Malabon-Navotas River. On the other hand, mouth sediment of the Parañaque River yielded the highest chromium and copper MECs for the Bay with the maximum values of 153.97 and 410.92, respectively. For Cr, RQ > 1 was more pronounced in Bulacan River, an area associated with tanneries which is a potential Cr source, and in Paranaque River. Pasig River also contributes sediment with high metal loads into the Bay. Based on RQs, Hg appears to be widely distributed in the sediment. Jewelry-making may be one of the major contributors of mercury in the bay.

For the pesticides, the data shows the persistence of some organochlorines in the sediment despite their restricted status. For instance, DDT has already been banned for agricultural and health uses; endosulfan is currently restricted for institutional use only; aldrin was registered for termite control but is currently not marketed in the country; and lindane is not widely used. However, these pesticides continue to be detected in the sediment indicating their persistence.

PAH levels in the eastern area which is 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 and suggesting localized risks The PRRP 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 health effects in various marine organisms. Consumption of aquatic organisms contaminated with PAHs may also cause cancer in humans.

Santiago (1997) identified the PAHs in Manila Bay sediments as coming from petrogenic and pyrolytic sources. Petrogenic sources PAHs come from oil discharges from ships, refineries, and industries while 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.

### 6.2.3. Tissues

The contaminants examined in tissues of fish and shellfish are coliforms, heavy metals, pesticides and toxic algae.

The $RQ_{Geomean}$ exceeded one for fecal coliform in shellfish and for Hg in pelagic fish. The $RQ_{Max}$ exceeded one for Pb in pelagic and demersal fish and in shellfish including bivalves. $RQ_{Max}$ also exceeded one for the other heavy metals such as Pb, Cu, Hg and Zn in shellfish. Among the pesticides, $RQ_{Max}$ exceeded one for aldrin and heptachlor in fish and endosulfan sulfate, endosulfan I and endrin in shellfish.

The highest $RQ_{Geomean}$ of 2,667 was obtained for fecal coliform in oyster samples from Bacoor, Cavite collected during the wet season in 1998. For mussels, the highest annual $RQ_{Geomean}$ of 467 was obtained for samples collected from Paranaque in 1997. Most of the calculated RQs for fecal coliform are below 300 but definitely much greater than one. The principal source of these bacteria is untreated domestic sewage. In general, the fecal coliform levels in shellfish tissues are higher during the wet season than during the dry season.

The $RQ_{Geomean}$ for all the pesticides examined are less than one. The $RQ_{Max}$ exceeded one for aldrin and heptachlor in fish and for endosulfan sulfate and endosulfan I in shellfish from Malolos, Bulacan and Bacoor, Cavite. The major possible source of pesticides in the bay is run-off 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 might be alarming at present, the results of the risk assessment signal cause for concern particularly for the endosulfans in shellfish, and aldrin and heptachlor in fish. It should also be borne in mind that pesticides can be persistent and cumulative such that chronic effects may become apparent over time.

HAB or toxic algae is episodic such that the RQ approach could not be applied directly. However, predictive models based on assessment of factors favorable for a bloom are useful in managing the risks of paralytic shellfish poisoning. It is noted that the levels of certain contaminants in the Bay which favor a bloom are high.

The results of the prospective risk assessment highlight the urgent need for decisive steps to reduce the disturbing levels of fecal coliforms in the bay which have also contaminated shellfish. Among the heavy metals, Hg and Pb in fish and shellfish should be monitored, considering their relative toxicity. Efforts at monitoring for pesticides and toxic algae are deemed necessary on the basis of the results of prospective risk assessment. The sources of these contaminants in the water column and sediment which eventually work their way to fish and shellfish and ultimately to man, should be controlled more effectively.

# 7. DATA GAPS AND UNCERTAINTIES

## 7.1. Retrospective Risk Assessment

Retrospective risk assessment was not carried out for some resources and habitats due to lack of historical data which can be the basis for comparison with their present state. The Refined Risk Assessment also identified other data that would be necessary as starting points for socio-economic analysis and management of fisheries/shellfisheries in the bay. These required data are:

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 (market and non-market values) would be necessary for the development of a model describing fish and shellfish population dynamics and hence indicative of sustainable and efficiency yields. For shellfish, production data for oysters and mussels were available from 1990 to 1997; however, point sources within the bay were not identified. Production operational costs for shellfisheries need to be gathered. Data on tissue quality and information on the possible health implications of coliform contamination should be gathered.

2. For seagrass, seaweed, coral reefs, mudflats, sandflats, 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, sandflats, beaches and rocky shores.

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

4. For shoreline and oceanographic changes, more data or research efforts should be directed at their impact on resources and habitats. More information should be collected to substantiate bottom topography changes, currents and wave patterns, and its direct and indirect impact to resources and habitats.

## 7.2. Prospective Risk Assessment (Contaminants)

The following data gaps were identified during the IRA phase but which could still not be addressed during the Refined Risk Assessment:

1. The PRRP (1999) data covered almost the entire Bay but the possible point sources (e.g., river mouths) and area sources were not taken into consideration.

2. Coliform data were generated for bathing beaches in the eastern portion of the Bay only. No such data were collected for the entire Bay as well as the northern and western portions of the Bay.

3. For sediments, new data and information were contributed by the study of Duyanen (1995) on metal concentrations in Manila Bay sediments. A few data sets were culled out from the abstract of the study conducted by Bajet *et al.* (1998) on pesticides levels in sediments.

4. There is no data available locally on contaminants associated with anti-fouling paints in ships. These are potentially important contaminants considering the volume of shipping in Manila Bay.

5. There was a lack of appropriate criteria for some pesticides, metals, and organic substances.

Other substances that should be given attention in risk assessment are the POPs and substances that have been identified to possess endocrine-disrupting effects.

Another source of risk that has been addressed in a preliminary way comes from accidental spills from shipping activities. The concerns include the likelihood of occurrence of accidents and the consequent likely exposure. These are related to the following aspects: rate of ship movement into and out of the bay; quantity and nature of cargo; experience of crew; age of vessel; operating procedures on safety; weather conditions; and other factors. The only data obtained so far are the number of oil spill incidents as well as the volume of oil spilled into the bay. 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.

Apart from oil spills, accidental release of toxic chemicals by cargo vessels is also a concern in the bay. Such releases could pose risks to biota and ecosystems in the bay.

Aside from accidental oil spills from shipping, operational discharges from stationary sources, e.g., refineries and industrial installations, should also be addressed. Discharges from refineries and manufacturing plants could be in the form of oil and toxic chemicals detrimental to the survival and growth of ecological systems.

## 7.3. PROSPECTIVE RISK ASSESSMENT (HUMAN HEALTH)

From the viewpoint of prospective (human health) risk assessment, the following are considered as data gaps:

1. Lack of data on concentrations of pesticides, heavy metals and coliforms in fish and shellfish in the western section of the bay. Most of the data for these agents pertain to the eastern section only. At any rate, the eastern section is more populated and industrialized than the western section; as such there are more sources for the input of these agents into the bay. The calculated risk estimates may be overestimates if applied to the western section.

2. There are no Philippine TDI values, much less age-specific TDI values.

3. There are no available data on doses that can be considered as toxic to humans.

# 8. RECOMMENDATIONS AND PROPOSED ACTIONS

## On Resources

1. **Strengthen fisheries and shellfisheries management in Manila Bay.**

The decreasing trends in 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. Over-harvesting and over-collection have been identified as the main causes 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. 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 risk assessment clearly indicate that fisheries and shellfisheries in Manila Bay are at risk and call attention to the strengthening of fisheries and shellfisheries management in the bay. It is recommended that maximum sustainable yield, dynamic maximum efficiency yield, and depreciation values be determined. As an alternative, imposition of partial fishing ban should be analyzed for related costs and benefits.

2. **Include in the overall Operational Plan for the Manila Bay Coastal Strategy interventions that will help in the recovery or restoration of the resources at risk.**

## On Habitats

3. **Conduct cost-benefit analysis of restoration of mangroves and protection of corals as part of the Operational Plan for the Manila Bay Coastal Strategy.**

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?".

4. **Require economic benefit-cost analysis of all reclamation projects as part of government approval process.**

5. **In coming up with land and water use plans as part of the Operational Plan for the Manila Bay Coastal Strategy, aim for an appropriate balance between the resources of the bay and economic activities.**

Tradeoffs should be identified and the comparative value among the schemes, especially in terms of the resources and corresponding economic activities should be evaluated.

6. **Laws and regulations on zoning and bay use should be strictly enforced.**

7. **Support research and development (R & D) efforts designed at addressing identified data gaps on resources and habitats.**

### ON SHORELINE

8. **Regulate or reduce extensive land reclamation activities especially real estate development near coastal areas, and enforce strict implementation and compliance to existing land use zoning plan of the coastal municipalities;**

9. **Intensify mangrove rehabilitation not only to sustain spawning ground for marine resources (e.g. fisheries and shellfisheries) but also to serve as ~~a~~ natural barriers to shoreline updrift and progradation.**

### ON BOTTOM TOPOGRAPHY AND BATHYMETRY

10. **Implement proper intervention that will reduce siltation and sediment deposition in the bay resulting from man made activities particularly agriculture, aquaculture, including continuous denudation of its watershed areas.**

This can be achieved through the installation of a soil diversion canal that will serve as catchment structure for soil erosion and surface run-off in any big project requiring massive earth movement. Moreover, strict compliance with land-use zonation plan should be imposed in order to regulate illegal land development, like illegal aquaculture farming and land conversion.

11. **Enforce strictly rules and regulations against dumping of dredge materials.**

### ON ECOLOGICAL RISKS

12. **Prioritize the contaminants for risk management of the ecosystem.**

In terms of ecological impact as indicated by the relatively high RQs observed, the contaminants of concern in the water column and sediment, respectively, can be ranked as follows:

Water column:
Coliforms > Nutrients (Phosphate) > Pesticides (Heptachlor) > Oil and Grease

Sediment:
Heavy Metals (Hg and Cu) > Heavy Metals (Pb, Zn, Cd, Cr) > TPAH

Cost-effective risk management actions to reduce the levels of these contaminants should be identified and prioritized.

13. **Set-up properly designed long-term monitoring programs of contaminants.**

A continuous monitoring program should be designed to keep track of existing contaminants as well as detect emerging contaminants that might pose risks in the future. There is a need to use reliable and accurate data in risk assessment. Secondary data that were available were of varied quality and quantity. Large variability in MEC values led to uncertainty in risk assessments for most contaminants. Future monitoring programs should be properly designed in line with the data requirements of risk assessment and should consider the adoption of appropriate QA/QC in sample collection, analysis and reporting of results. For instance, the detection limits for pesticides should be improved through adoption of more sensitive techniques or acquisition of more sensitive equipment. Most pesticides are carcinogenic and therefore it is important to set up a reliable monitoring program for pesticides in water, sediment, and especially tissues.

**14. Establish appropriate Philippine threshold values based on scientific data and information.**

The use of threshold values (criteria and PNECs) appropriate to Manila Bay will reduce uncertainties in risk assessment significantly. The prospective risk assessment used a number of criteria values from different sources and jurisdictions. Basically, the officially adopted Philippine criteria values were used and in the absence of these for a number of contaminants, criteria values from other areas were adopted. There is a need to rationalize the choice of the criteria and PNECs used in risk assessment. There is also a strong need to review the DENR DAO 34 water quality criteria for heavy metals, considering the wide disparity in the values adopted for copper, mercury and lead (at least an order of magnitude higher) compared to the US EPA marine chronic and acute criteria for regulatory purposes.

In the refined risk assessment, both the HK ISQV and shale values for metals in sediment were used as PNECs. Although admittedly, the shale values represent baseline values which are more conservative than the HK ISQV which give threshold values, the RQs based on the shale values were also presented for comparison. The RQ values thus obtained were different depending on which PNEC was used.

There is a need to establish PNECs for certain pesticides, particularly those which are no longer in use abroad and for which no PNEC has been established.

**15. Develop models that can be useful in predicting and validating concentrations of contaminants and their transport.**

The use of appropriate models to predict and validate contaminant load, concentration levels, and dispersion and transport of contaminants are particularly relevant for determination of nutrient loads and prediction of transport and impact areas of oil spills and toxic chemical discharges.

**16. Support initiatives for the gathering of new data on contaminants that present ecological and health risks but for which data are not available at the time of the risk assessment process.**

Measurement of the following contaminants for which data are not available at the time of the risk assessment process should be supported: PAHs, pyrethroids and POPs, organotins, and substances that exhibit endocrine disruptive effects.

## ON HUMAN HEALTH RISKS

**17. Identify and prioritize the management of contaminants that pose human health risks.**

Among the contaminants examined, the following should be given immediate and long-term solutions based on measured concentrations of these contaminants against the predicted no-effects concentration.

> fecal coliforms in shellfish > lead and mercury in fish and shellfish > pesticides (heptachlor and aldrin in fish and endoslfan sulfate, endosulfan I and endrin in shellfish).

**17.1. Risks to Human Health from Coliform Contamination**

Human health risk arises from fecal coliform contamination of the water column and in seafood tissues. 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 avoid human health problems:

- Regulate food supply from heavily coliform-contaminated bivalve-growing areas and the use of contaminated beaches and bathing stations; and

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

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 risk assessment has determined these as priority areas for consideration as part of the long-term risk management program:

- Accelerate sewage collection and treatment programs in highly urbanized and industrialized areas of the Manila Bay area;

- 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;

- Gather secondary data on coliform contamination or coliform loadings for all major tributaries. Use models to determine transport from outfalls and spatial distribution in the bay and to study seasonal effects on coliform levels;

- Perform benefit-cost analysis to identify appropriate interventions; and

- Provide incentives to proponents of success stories (i.e. sewage treatment facilities).

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

### 17.2. Risks to Human Health from Heavy Metals and Pesticides

Risks to human health are associated with relatively high (although localized) levels of some metals and pesticides in seafood tissue. Data that are presently available on which the RQs were based, are limited, especially for pesticides. Additional tools should be used to verify the risks to these agents, such as:

- The conduct of rapid appraisal of heavy metal and pesticide loadings in the bay;

- The use of models to predict the fate of heavy metals and pesticides in the bay and estimate the levels in water, sediments and tissue; and

- The setting-up of monitoring programs for heavy metals and pesticides in the bay.

## 18. Establish appropriate local Tolerable Daily Intake (TDIs) for different age groups.

Local values for TDIs should be established by appropriate regulatory agencies particularly for agents that may have cumulative effects or for which critical populations exist. Such agents include heavy metals and pesticides, particularly persistent organic pesticides (POPs).

**19. Review existing laws, ordinances and regulations and strengthen enforcement of these by concerned agencies and LGUs. Build technical capabilities of LGU's on law enforcement and in monitoring.**

**20. Eliminate direct dumping and discharges of untreated domestic, industrial, health-care, and agricultural waste, including septic or sludge disposal to Manila Bay and its tributaries.**

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

**22. Provide safe potable water supply to households.**

**23. Identify other pathways of human exposure from contaminants of Manila Bay (e.g. skin adsorption, contact with contaminated soil, etc)**

**24. Implement related research and development projects.**

Morbidity or mortality rates due to contaminants such as coliforms in the bay cannot be established, as these same contaminants may be present in other areas aside from Manila Bay. Additional site-specific studies such as biomarker study and demographic survey are needed to establish causal relationship with the agent of concern. Exposure assessment of critical populations (e.g. children, pregnant women) coupled with appropriate biomarkers for heavy metals (Hg and Pb) and pesticides (heptachlor and aldrin) should be pursued. Through biomarker studies, linkages of the causes of diseases can be established.

Implement related research and development projects, particularly on bioremediation measures to reduce the levels of harmful contaminants in the bay and to establish the concentrations of agents in fish and/or shellfish for which there are no data (organotins, POPs, PAHs).

## ON HARMFUL ALGAL BLOOM

**25. Optimize monitoring and management efforts in relation to harmful algal blooms by including:**

- Coordination with the monitoring of environmental parameters in the bay with existing related projects/programs;
- Monitoring of the phytoplankton species composition useful in predicting possible harmful algal bloom in key areas (Bataan and Cavite);
- Monitoring of shellfish for other algal biotoxins;
- Use of available tools for detection of other algal biotoxins; and
- Consideration of risks of getting other harmful algal cells/cyst from ship ballast waters.

**26. Ensure proper management of aquaculture farms to control nutrient loading to levels that will not trigger HAB.**

# APPENDICES

## Appendix 1a. Summary of Likelihood of Some Identified Agents Causing Decline in Resources

| Resource | Likely | Possibly | Unlikely | Unknown |
|---|---|---|---|---|
| Fisheries | Overfishing (Growth overfishing and recruitment overfishing) | TSS<br>Pesticides<br>DO/BOD/COD<br>Oil & grease<br>Oil spills<br>Heavy metals<br>Nutrient Load | Coliforms<br>TOC<br>Solid waste<br>PAH<br>Lahar flow | PCBs, TBT and other organic toxicants<br>Algal blooms, precipitate from air pollutants |
| Shellfisheries | Overfishing/ Over collection<br>DO/BOD/ COD | Heavy metals<br>Pesticides<br>TSS<br>Oil & grease<br>Oil spills<br>PAH<br>Destruction of habitat<br>Plankton blooms | Nutrients<br>Coliforms<br>TOC | PCBs, TBT and other organic toxicants |
| Seaweeds/ algae | Collection<br>TSS<br>Proliferation of *baklads* | Heavy metals<br>Pesticides<br>Oil & grease<br>Oil spills | Coliforms<br>Nutrients<br>TOC<br>DO/BOD/COD<br>PAH | PCBs, TBT and other organic toxicants<br>Algal blooms |
| Phyto plankton | TSS | Oil & grease<br>Oil spills | PAH<br>Heavy metals<br>Pesticides<br>Coliforms<br>Nutrients<br>TOC<br>DO/BOD/COD | PCBs, TBT and other organic toxicants |

## Appendix 1b. Summary of Likelihood of Some Identified Agents Causing Decline in Habitats

| Habitat | Likely | Possibly | Unlikely | Unknown |
|---|---|---|---|---|
| Mangroves | Clearance (conversion for aquaculure & salt beds/ reclamation)<br><br>Physical disturbance<br>Sedimentation<br>Solid waste | Insect infestation (in some areas)<br>Oil & grease<br>Oil spills<br>Pesticides | Heavy metals<br>Coliforms<br>Algal blooms<br>TOC<br>DO/BOD/COD<br>Nutrients | PCBs and other organic toxicants |
| Coral Reefs | Sedimentation<br>Collection<br>Physical disturbance (e.g., boat anchorage; inappropriate fishing methods) | Oil & grease<br>Oil spills<br>Nutrients | PAH<br>Pesticides<br>Heavy metals<br>Coliforms<br>TOC<br>DO/BOD/COD | PCBs and other organic toxicants<br>Algal blooms |
| Seagrass | TSS/sedimentation<br>Conversion of coastal areas for open water fish culture | Oil & grease<br>Oil spills<br>Destructive fishing methods | Heavy metals<br>Pesticides<br>Coliforms<br>Nutrients<br>TOC<br>DO/BOD/COD<br>PAH | PCBs and other organic toxicants<br>Algal blooms |
| Soft-Bottoms | Sedimentation (reclamation)<br>Physical Destruction/ Disturbance from fishing activity (i.e., bottom trawling)<br>DO/BOD/COD | TSS<br>Heavy metals<br>Pesticides<br>Oil & grease<br>Oil spills | Nutrients<br>Coliforms<br>TOC<br>PAH | PCBs, TBT and other organic toxicants<br>Algal blooms |
| Mudflats | | Reclamation<br>Conversion | | |
| Sand flats and Beaches | | Reclamation<br>Conversion<br>Pollution | | |
| Rocky Shores | | Reclamation<br>Conversion<br>Physical Destruction | | |

## Appendix 1c. Summary of Likelihood of Some Identified Agents Causing Changes in Shoreline and Bathymetry.

| Habitat | Likely | Possibly | Unlikely | Unknown |
|---|---|---|---|---|
| Bathymetry/ sea depth | • Sediment deposition (TSS)<br>• Lahar flow (via Pampanga River)<br>• Man-made activities like land reclamation | | | |
| Shoreline | Progradation due to<br>• Man-made activities (i.e. land reclamation)<br>• Increased sediment input due to river works for flood mitigation project & deforestation<br>• Natural factor like lahar deposition<br><br>Shoreline erosion due to:<br>• Decrease sediment input from inland due to dam & other river works | • Global & local sea level rise | | |

## Appendix 2. Sources of Data

### 2a. Retrospective Risk Assessment

| Resource/ Habitat | References |
|---|---|
| Fisheries | BFAR, 1995 |
| | Tambuyog Development Center, 1990 |
| | FSP-DA, 1992 |
| | UNEP/EMB-DENR, 1991 |
| | MADECOR and National Museum, 1995 |
| | Armada, 2001 |
| | Silvestre et al, 1987 |
| Shellfisheries | UNEP/EMB-DENR, 1991 |
| | Tambuyog Development Center, 1990 |
| | Blanco, G. J., 1958 |
| Seaweeds | BFAR, 1995 |
| | Bonga et al., 1996 |
| Phytoplankton | BFAR, 1995 |
| Mangroves | BFAR, 1995 |
| | DENR-RIII, 1999 |
| | DENR-NCR, 1999 |
| | Bonga et al., 1996 |
| Corals | BFAR, 1995 |
| | UNEP/EMB-DENR, 1991 |
| | Bonga et al., 1996 |
| Soft-Bottoms | PRRP, 1999 |
| | BFAR, 1995 |
| | UNEP/EMB-DENR, 1991 |
| Seagrass | BFAR, 1995 |
| | Bonga et al., 1996 |
| Mudflats, Sandflats, Beaches and Rocky Shores | BFAR, 1995 |
| Shoreline, Bathymetry and other Physical Features | Siringan et al., 1997, 1998 |
| | PNOC-PDC EIS 1994 |

## 2b. Prospective Risk Assessment

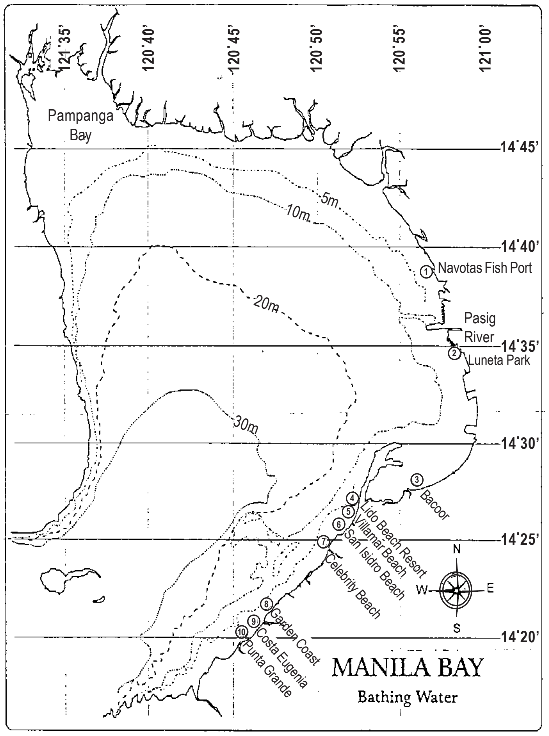
| Parameters | Description of Data | Location | References |
|---|---|---|---|
| **Nutrients** | Raw data: 1996-1998, monthly, 8 stations, 3 depths (SMB) | Entire bay | PRRP, 1999 |
| **DO** | Raw data: 1996-1998, monthly, 8 stations, 3 depths (SMB) | Entire bay | PRRP, 1999 |
| **TSS** | Raw data: 1996-1998, 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 |
| | Raw data: 18 stations, 3 depths, November 1998 | Entire bay | Velasquez et al., , 2002 |
| Sediment | Raw data: -164 sampling stations; 8 metals (Cd, Cr, Co, Cu, Pb, Hg, Ni, Zn) | 14.43 - 14.80ºN Lat. (entire bay) | Duyanen, 1995 |
| Tissue<br>Fish | Raw data: 1994 and 1996, 16 fish species (demersal and pelagic) | Purchased from ports at Coastal Road, Parañaque (April 1994) and Naic, Cavite (March 1996) | Prudente et al., 1997 |
| Shellfish | Raw data: 5 stations, September and March 1996 | Bulacan, Parañaque, Bacoor, Kawit and Naic, Cavite | PRRP, 1999 |
| | Averages: 3 stations, May and August 1993 | Parañaque, Pampanga, Bataan | BFAR, 1995 |
| **Pesticides** | | | |
| Sediment | Organaochlorine pesticides (HCB, Aldrin, Dieldrin, Lindane, DDT, DDE, DDD, Endosulfan I, Endosulfan II and Endosulfan Sulfate | Mouths of rivers draining to Manila Bay: 14-25 tributaries | Bajet *et al.*, 1998 |
| Sediment<br>16 pesticides | Raw data: Sept and Mar 1996; 10 stations | Entire bay | PRRP, 1999 |
| Tissue (Shellfish)<br>16 pesticides | Raw data: Sept and Mar1996; 5 stations | Bulacan, Parañaque, Bacoor, Kawit and Naic, Cavite | PRRP, 1999 |
| (Fish)<br>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 |

## 2.b. Prospective Risk Assessment (cont.)

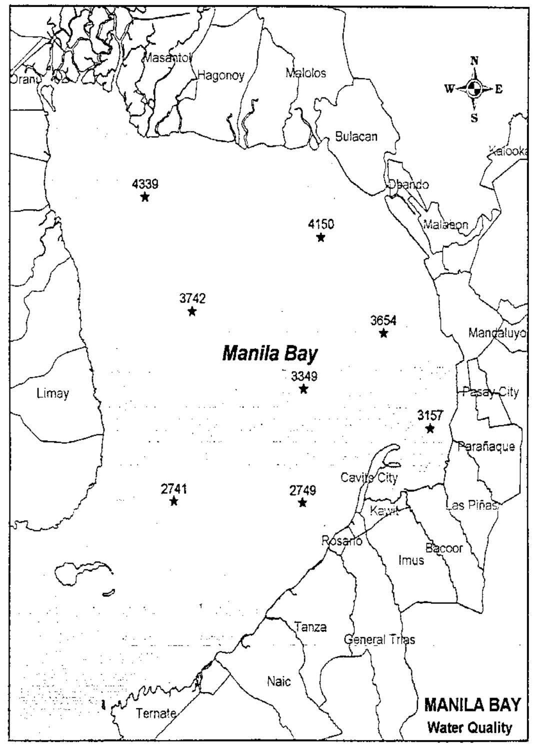
| | | | |
|---|---|---|---|
| **Oil and grease** | 1985 | Bacoor (Cavite), Pasig (Manila), Navotas (Metro Manila), Meycauayan and Pamarawan (Bulacan) | Cited in BFAR, 1995 |
| | 1992-1993 | Around the bay | BFAR, 1995 |
| | 2001: 5 stations | Offshore areas | EMB and PCG activity |
| **Oil spills** | 1990-2001: Source, date, area, type and quantity of oil | Bataan and Manila | 1990-2001:<br>PCG, 2002 Report (unpublished) |
| **Marine debris** | 1999: distance covered, amount, and type of marine debris collected in NCR and Regions 3 and 4 | Manila, Bataan, Bulacan, Cavite | International marinelife Alliance Center for Marine Conservation |
| **Harmful Algal Blooms** | List of harmful algae detected in Manila Bay | | Azanza and Miranda, 2001; GEOHAB, April 2001 |
| | 1988-2000: Paralytic shellfish poisoning cases in Manila Bay | | IACEH-DOH |
| | Physico-chemical factors favorable for *Pyrodinium* growth | | Usup and Azanza, 1998; Bajarias and Relox, 1996; Estudillo and Gonzales, 1983 |
| | 1998: Monthly cell density of *P. bahamense* and toxin levels in mussels | | BFAR, 1998 |

## Appendix 3. Sampling Stations in Manila Bay Used in the Pasig River Rehabilitation Project (1999).

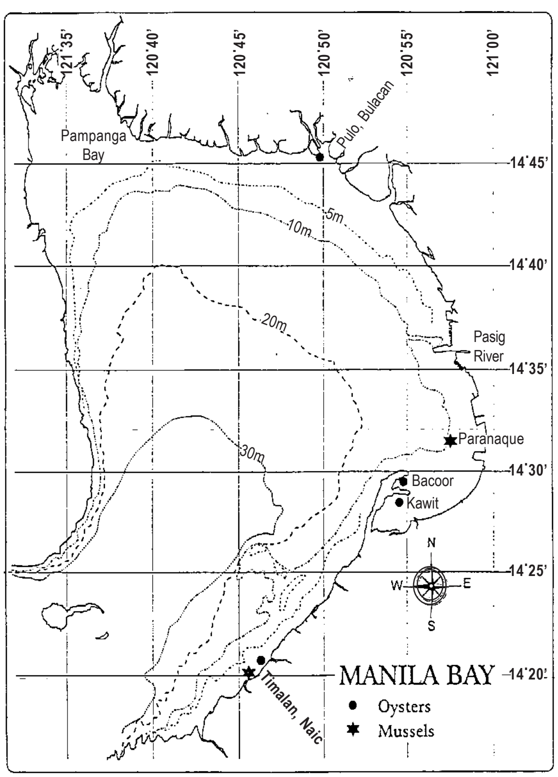
**(a)**



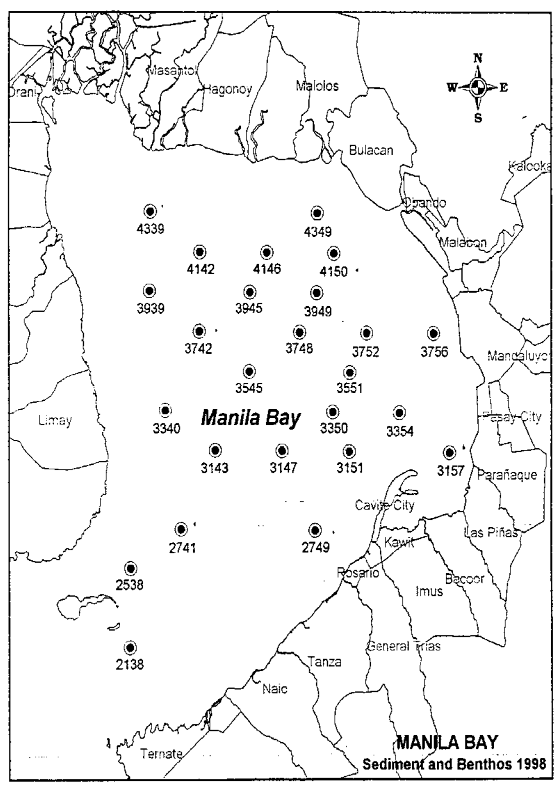

**(b)**




**(c)**




**(d)**



## Appendix 4. Criteria/Standards

### Appendix 4a. Water Quality Criteria

| Agent | U.S. EPA Quality Criteria for water for regulatory purposes (USEPA, 2000) | | Water Quality Criteria for coastal and marine waters in the Philippines (DAO 34) (Classes SA, SB, SC, SD) (DAO 34, 1990) | ASEAN (Marine water quality criteria) (ASEAN, 2003) | Chinese Standards for different classifications (Classes I, II, III, IV) (National Statistics of PR China, 1995) |
|---|---|---|---|---|---|
| | 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 | |
| Nitrite (mg/l) | | | | 0.055 | |
| Phosphate (mg/l) | | | | 0.015-0.045 (coastal - estuaries) | |
| TSS (mg/l) | | | | 50 (Malaysia) | |
| Cyanide (μg/l) | 1 | 1 | 50,50,50,? | 7 | 5,5,100,200 |
| Ammonia (μg/l) | | | | 70 (unionized) | |
| **Heavy Metals (μg/l)** | | | | | |
| Cadmium | 43 | 9.3 | 10,10,10,? | 10 | 1,5,10,10 |
| Copper | 2.9 | 2.9 | ?,20,50,? | 8 | 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) | 50 (VI) | 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 |

? - No value specified

**Appendix 4a. (continued) Water Quality Criteria**

| Agent | 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 (Marine water quality criteria) | Chinese Standards for different classifications (Classes I, II, III, IV) |
|---|---|---|---|---|---|
| | Marine acute criteria | Marine chronic criteria | | | |
| **Trace Organics (µg/l)** | | | | | |
| 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 |
| *Organometallics* | | | | | |
| TBT (ug/l) | | | | 0.01 | |
| | | | | | |
| Oil & grease (mg/l) | 0.09 | 0.004 | 1,2,3,5 (Petroleum ether extract) | 0.14 (Water soluble fraction) | 0.05,0.05,0.3,0.5 |

? - No value specified

## Appendix 4b. Sediment Quality Criteria

| Agent | HK-ISQVs (EVS, 1996) | | CANADA (Environment Canada, 1995) | | NOAA (Long, et al., 1995) | | NETHERLANDS (MTPW, 1991) | |
|---|---|---|---|---|---|---|---|---|
| | Contamination Classification | | Threshold/probable Effects Level | | Effects Range | | Provisional Test/warning Value | |
| | Lower limit | Upper limit | Threshold | Probable | Low | Median | Test | Warning |
| **Heavy Metals (mg/kg)** | | | | | | | | |
| 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 |
| **Organics (µg/kg)** | | | | | | | | |
| Acenaphthene | 16 | 500 | [6.71] | [88.9] | 16 | 500 | - | - |
| Acenaphthylene | 44 | 640 | [5.87] | [245] | 44 | 1100 | - | 300 |
| Anthracene | 85.3 | 1,100 | [46.9] | [128] | 85.3 | 640 | 80 | |
| Fluorene | 19 | 540 | 21.2 | [144] | [19] | 540 | - | - |
| Naphthalene | 160 | 2,100 | 34.6 | [391] | 160 | 2,100 | - | - |
| Phenanthrene | 240 | 1,500 | 86.7 | 544 | 240 | 1,500 | [80] | [300] |
| Low mol. wt. PAHs | 552 | 3,160 | - | - | 552 | 3,160 | - | - |
| Benzo[a]anthracene | 261 | 1,600 | [74.8] | 693 | 261 | 1,600 | 80 | [300] |
| Benzo[a]pyrene | 430 | 1,600 | 88.8 | 763 | 430 | 1,600 | 80 | [300] |
| Chrysene | 384 | 2,800 | 108 | 846 | 384 | 2,800 | [80] | [300] |
| Dibenzo[a,h]anthracene | 63.4 | 260 | [6.22] | [135] | 63.4 | 260 | 80 | 300 |
| Fluoranthene | 600 | 5,100 | [113] | 1494 | 600 | 5,100 | 200 | [700] |
| Pyrene | 665 | 2,600 | 153 | 1,398 | 665 | 2,600 | [80] | [300] |
| High mol. wt. PAHs | 1,700 | 9,600 | - | - | 1,700 | 9,600 | - | - |
| Total PAHs | 4,022 | 44,792 | - | - | 4,022 | 44,792 | [460] | [1,700] |
| Total PCBs | 22.7 | ns | 21.5 | 189 | 22.7 | 180 | [20] | [40] |

### Appendix 4b. (Continued) Sediment Quality Criteria

| Agent | HK-ISQVs | | CANADA | | NOAA | | NETHERLANDS | |
|---|---|---|---|---|---|---|---|---|
| | Contamination Classification | | Threshold/probable Effects Level | | Effects Range | | Provisional Test/warning Value | |
| | Lower limit | Upper limit | Threshold | Probable | Low | Median | Test | Warning |
| **Organics (µg/kg)** | | | | | | | | |
| p,p'-DDE (4,4'-DDE) | 2.2 | ns | [2.07] | 374 | 2.2 | [27] 1 | - | - |
| Total DDT | 1.58 | ns | 3.89 | 51.7 | [1.58] | [46.1] 2 | 2 | 50 |
| Bis(2-ethylhexyl)phthalate | | | 182 | 2647 | | | | |
| Chlordane | | | 2.26 | 4.79 | | | | |
| Lindane | | | [0.32] | 0.99 | | | | |
| Organometallics | | | | | | | | |
| TBT in interstitial water (µg/l) | 0.15 | ns | | | | | | |

### Appendix 4c. Human Health Guidelines

| Heavy metals | TDI in µg/person/day (mostly from FDA, USA) (MPP-EAS, 1999b) | Level of Concern µg/g in seafood (low consumption group, 49 g/person/day) | Level of Concern µg/g in seafood (high consumption group, 181 g/person/day) |
|---|---|---|---|
| Arsenic | 130 | 2.65 | 0.72 |
| Cadmium | 55 | 1.12 | 0.30 |
| Chromium | 200 | 4.08 | 1.10 |
| Copper | 400 (1-10yr) | 8.16 | 2.21 |
| | 2,000 (adults) | 40.82 | 11.05 |
| Iron | 8,000 (1-10 yr) | 163.27 | 44.20 |
| | 14,000 (adults) | 285.71 | 77.35 |
| Mercury | 16 | 0.33 | 0.09 |
| Manganese | 1,000 (1-10 yr) | 20.41 | 5.52 |
| | 2,500 (adults) | 51.02 | 13.81 |
| Nickel | 1,200 | 24.49 | 6.63 |
| Lead | 6 (0-6 yr) | 0.12 | 0.03 |
| | 15 (7-adults) | 0.31 | 0.08 |
| | 25 (pregnant women) | 0.51 | 0.14 |
| | 75 (adults) | 1.53 | 0.41 |
| Zinc | 5000 (1-10 yr) | 102.04 | 27.62 |
| | 15,000 (adults) | 306.12 | 82.87 |

**Appendix 4c. Human Health Guidelines**

| | TDI in µg/person/day (MPP-EAS, 1999b) | Level of Concern in µg/g in shellfish (consumption rate: 16 g/person/day) |
|---|---|---|
| *Pesticides* | | |
| Chlordane | | |
| DDT/DDE | 80 | 5 |
| Endosulfan | 4.8 | |
| Heptachlor | 4.8 | 0.3 |
| Endrin | 4.8 | |
| Aldrin | 4.8 | 0.3 |
| Dieldrin | 4.8 | 0.3 |
| Lindane | 1.6-8 | 0.1-0.5 |
| | | |

| 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** |

*** Waldock, 1994 and Willows, 1994*
** Langston, 1996*

| PSP toxins | BFAR - Philippines | US FDA guideline |
|---|---|---|
| PSP | 40 µg/100g shellfish tissue | 400 MU (about 80 µg/100g shellfish tissue) |

## Appendix 5: Decision Criteria for Retrospective Risk Assessment

| Case | Result of Decision Tables | Conclusion |
|---|---|---|
| A | No 1 & 2 = unlikely (U) | No correlation |
| B | Yes 1 & 2, ND for 3 – 6 = possibly (P) | Just correlation |
| C | Yes 1 & 2, but No 3 = unlikely (U) | Correlation but negative evidence for cause-effect |
| D | Yes 1 & 2, but No 6 = unlikely (U) | Spurious correlation |
| E | Yes 1, 2, & 3 = likely (L) | Correlation with some evidence of cause-effect |
| F | Yes 1, 2, & 3, but no 4a = unlikely/possibly (U/P) | Correlation but negative evidence for cause-effect; if good experimental design (e.g., low Type II error = unlikely), with poor experimental design (e.g., high Type II error) = possibly. |
| G | Yes 1, 2, & 3, ND for 4a, but no 4b = possibly (P) | Correlation but lack of evidence for cause-effect |
| H | Yes, 1, 2, 3, & 4a, but no 4b = likely (L) | Correlation with evidence for cause-effect and recovery does not always occur |
| I | Yes, 1, 2, 3, 4a, & 5 = very likely (VL) | Correlation with strong evidence for cause-effect |
| J | Yes, 1, 2, 3, & 4a, but no 5 = likely (L) | Correlation with evidence for cause-effect (a lack of biomarker response is inconclusive evidence) |
| K | Yes, 1, 2, 3, 4a, 5, & 6 = very likely (VL) | Correlation with very strong evidence for cause-effect |
| L | Yes, 1, 2, 3, but maybe 6 = possibly (P) | Correlation but scientific/logical justification lacking |
| M | Yes 6 but no data for 1 & 2 = don't know (DK) | Cause – effect relationship known to be possible in principle, but no evidence in this case |
| N | Yes 1, but no 2 | Target is exposed but there is no evidence for decline; if there is good evidence for no decline then no need to take risk assessment further; if evidence for no decline is weak or questionable seek more evidence |