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The Report Of The Ecology And Welfare Subcommittee

ENVIRONMENTAL PROTECTION AGENCY
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Relative Risk Reduction Project

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ABSTRACT

The Ecology and Welfare Subcommittee of the Relative Risk Reduction Strategies Committee (RRRSC) of the U.S. Environmental Protection Agency's Science Advisory Board (SAB) reviewed the ecological and welfare components of the Agency's 1987 report entitled "Unfinished Business: A Comparative Analysis of Environmental Problems". The Subcommittee was critical of the original EPA ranking of environmental problem areas that mixed sources, receptors, media, and specific regulatory obligations, since this categorization reflected EPA programmatic interests more than it provided a rational basis for evaluating environmental problems in the United States. In addition, some ecologically significant problems that were outside of EPA's regulatory purview were omitted. The Subcommittee was also critical of the welfare effects analysis, finding it to be defined too narrowly

The Subcommittee developed alternative methodologies for evaluating ecological and welfare risk assessments: a) aggregation of related EPA environmental problem areas into a more limited number of categories and then ranking those categories; and b) disaggregation of the initial EPA environmental problem areas into environmentally-relevant categories of stresses and then ranking those categories. The ecological problem areas that were consistently ranked the highest by the Subcommittee were habitat alteration, global climate change, and stratospheric ozone depletion.

The Subcommittee developed six major recommendations from its review of the Unfinished Business report: a) formalize an extramural and continuous process for ecological risk prioritization; this process should not be categorized by Agency programmatic structure but rather by anthropogenic stresses on the environment; b) invest in development of formal methodologies for ecological risk assessment; c) develop the data bases needed for improving future ecological risk assessments; d) develop an appropriate methodology for integrating ecological and economic time dimensions; e) EPA should give more consideration to non-economic aspects of ecological values and welfare risks; f) consider the results from this risk ranking process, including the 1990 risk reduction study, in development of future Agency policy and in allocation of financial resources.

The Subcommittee reached a strong consensus that the relative risk assessment process is a good mechanism to formulate public policy from a scientific base of data and mechanistic processes and recommended that the Agency institutionalize this approach on a regular basis, providing the trained personnel and scientific data-bases needed to establish a scientific credibility for the process.

<u>Key Words</u>: ecological risk assessment; risk reduction; welfare risk assessment

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1.0 EXECUTIVE SUMMARY

This is the report of the Ecology and Welfare Subcommittee of the Relative Risk Reduction Strategies Committee (RRRSC) of the U.S. Environmental Protection Agency's Science Advisory Board (SAB). As part of the overall activities of the RRRSC, the Subcommittee reviewed the Agency's 1987 report entitled "Unfinished Business: A Comparative Analysis of Environmental Problems" (EPA, 1987a,b,c), hereinafter referred to as Unfinished Business, in order to provide a peer-review and update of that document, develop alternative methodologies for evaluating ecological and welfare risk assessments, and combine ecological and welfare rankings of relative risk into a single aggregate ranking.

The Subcommittee members were unanimous in their dissatisfaction with the original EPA list of problem areas that mixed sources, receptors, media, and specific regulatory obligations (see Table III, page 10). In the Subcommittee's view, this categorization reflects EPA programmatic interests far more than it provides a rational basis for evaluating national environmental problems. In addition, the Subcommittee identified some significant environmental problems that were outside of EPA's regulatory purview and that had been excluded from the original list of problem areas (e.g., habitat alteration and depletion of species).

The Subcommittee strongly endorses the use of a matrix of ecological stress types versus ecosystem types as developed by Harwell and Kelly (1986) (see Table VI, page 19). We utilized our evaluations of the intensity of potential effects, the uncertainties of these estimates, the type of ecological responses, and the time scales for recovery following removal of the stress as diagnostic parameters. Once the hierarchy of relative risk was established, we aggregated the problem areas as to scale of stress (local, regional, biosphere), transport media (air, water, terrestrial), and recovery time (years, decades, centuries/ indefinite) (see Table I, next page).

The ecological problem areas that we consistently ranked the highest were habitat alteration , global climate change, and

Table I - Developing a Hierarchy of Relative Risk

Diagnostic Parameters	Aggregated Problem Areas
- Intensity of Potential Effects - Uncertainties of these Estimates - Type of Ecological Responses - Time Scale for Recovery Following Removal of Stress	- Scale of Stress (local, regional biosphere) - Transport Media (air, water, terrestrial) - Recovery Time (years, decades, centuries/indefinite)

stratospheric ozone depletion (see Table VIII, page 23). The time-space dimensionality of all three are similar. The ecological impacts are locally, regionally, and globally distributed, and the recovery times are estimated to be up to centuries. Ecological systems are well adapted to recover from many types of stresses as long as the impacted areas are patchy in distribution and asynchronous in time. This allows for genome refugia that constitute sources for recolonization once the stress is removed. Loss or disturbance of natural habitats increases the rate of biological depletion, which is the other problem area of high concern. The extinction of biologic species is an irreversible event with unknown, but long-term impacts. It is virtually impossible to ensure the survivorship of a species if its habitat cannot be protected.

The Subcommittee ranked the problem areas of airborne toxics, toxics in surface waters, and pesticides and herbicides in the second highest category of relative risk (see Table VIII, page 23). We gave emphasis to toxic substances (heavy metals and organics) that are transported by air and water and may be bioaccumulated in ecological food chains. Generally, these stresses do not cause irreversible impacts, but they do deplete the quality of the ecological resources and definitely interfere with the human uses of specific populations. The rapid transport processes in air and the large number of point and non-point discharges to surface waters generate local and regional impacts. The recovery times after the sources are removed are measured in multiple decades.

The Subcommittee discussed in depth the assessment of welfare risks. We felt that the traditional practice of discounting the values of impacts in time makes no sense ecologically. We defined four types of welfare impacts: ecological quality, resource sustainability, direct effects-economic, and direct effects-non economic (Table II). The ecological impacts are mediated through ecological processes and, therefore, the welfare and ecological rankings are similar. The resource sustainability impacts involve changes in the environment that are irreversible or of very long duration relative to human perspective. Again, the impacts are often mediated through ecological processes and, therefore, the welfare rankings are a sub-set of the long-duration ecological effects (this includes the issue of groundwater contamination).

Table II - Assessing Welfare Risks

Types of Welfare Impacts	Ranked	Definition
Ecological Quality	yes	Indirect impacts on humans that result from a reduced quality of an environmental resource and decreased human utility (Reversible)
Resource Sustainability	yes	Irreversible losses of ecosystem structure and functions, such as loss of critical habitat or species extinctions
Direct Effects - Economic	no	Direct physical changes that cause adverse economic impacts on humans other than health effects
Direct Effects-Non Economic	yes	Primarily involves social nuisances such as odors, noise, and reduced visibility

The direct effects-economic risks could not be ranked as the data needed to perform a credible benefit/risk analysis are not available. The Subcommittee did rank the direct effects-non economic risks. These involve noise, odor, vistas, and psychological impacts that are not easily quantified and for which no environmental standards exist.

We recognize that the authority to implement programs to address the environmental problems of greatest concern is distributed widely across the federal and state governments and, thus, beyond the mandate of the U.S. EPA. The Agency, however, is the only Federal agency whose primary mission is to "speak for the environment." The Agency must take an aggressive leadership role in demonstrating to other governmental institutions the risks and benefits of sound environmental planning and management.

The Subcommittee developed six major recommendations that result from our review of the Unfinished Business report and from our present evaluation of the environmental problems that were identified in Unfinished Business:

a) Formalize an extramural and continuous process for ecological risk prioritization; this process should not be categorized by Agency programmatic structure but rather by anthropogenic stresses on the environment.

b) Invest in development of formal methodologies for ecological risk assessment.

c) Develop the data bases needed for improving future ecological risk assessments.

d) Develop an appropriate methodology for integrating ecological and economic time dimensions.

e) EPA should give more consideration to non-economic aspects of ecological values and welfare risks.

f) Consider the results from this risk ranking process, including the 1990 risk reduction study, in development of future Agency policy and in allocation of financial resources.

The Subcommittee developed a strong consensus that the relative risk assessment process is a good mechanism to formulate public policy from a scientific base of data and mechanistic processes. We recommend that the Agency institutionalize this approach on a regular basis, and provide the trained personnel and scientific data-bases needed to establish a scientific credibility for the process.

2.0 INTRODUCTION

2.1 Background

In its 1988 report on research strategies for the 1990's, "Future Risk", the Science Advisory Board recommended that the concept of risk reduction be used more broadly in EPA (SAB, 1988). As a follow-up to that report, EPA Administrator William K. Reilly requested that the SAB bring its technical expertise to the task of developing risk reduction strategic options that will assist him in assessing possible Agency activities. In response to this request, the SAB formed the Relative Risk Reduction Strategies Committee (RRRSC).

A major portion of the RRRSC's work involves consideration of the 1987 EPA report "Unfinished Business: A Comparative Assessment of Environmental Problems" (EPA, 1987a,b,c). This EPA document reports on the findings of EPA senior staff who evaluated more than two dozen environmental problems in terms of their relative environmental risks. These problems were evaluated within four broad categories: cancer risk, non-cancer health risk, ecological risk, and welfare risk.

To evaluate these issues, the RRRSC formed three subcommittees. The Human Health Subcommittee was formed to evaluate the cancer and non-cancer health risks; the Ecology and Welfare Subcommittee was formed to evaluate the ecological and welfare risks; and the Strategic Options Subcommittee was formed to develop and evaluate risk reduction strategies. The charge to the SAB, through its RRRSC and three associated subcommittees, was to:

a) Provide a critical review of the "Unfinished Business" report that reflects any significant new information that bears on the evaluation of the risks associated with specific environmental problems.

b) Provide, to the extent possible, merged evaluations of cancer and non-cancer risks (i.e., health risks) and of ecological and welfare risks (i.e., environmental risks).

c) Provide optional strategies for reducing major risks.

d) Develop a long-term strategy for improving the methodology for assessing and ranking risks to human health and the environment and for assessing the alternative strategies that can reduce risks.

2.2 Charge to the Ecology and Welfare Subcommittee

This document was prepared by the Ecology and Welfare Subcommittee, a subcommittee of the Relative Risk Reduction Strategies Committee (RRRSC) of the U.S. Environmental Protection Agency's (EPA) Science Advisory Board (SAB). The tasks taken on by this Subcommittee were: a) to provide a peer review of the procedures utilized and the rankings obtained from the EPA activities in 1986-87 that led to the EPA report entitled "Unfinished Business: A Comparative Assessment of Environmental Problems"; b) to update the background papers presented in "Appendix III - Ecological Risk Work Group" (of the "Unfinished Business" report) and re-evaluate the ecological rankings based on this new information; c) to critique the procedures presented in "Appendix IV - Welfare Risk Work Group" (of the "Unfinished Business" report) and to develop an alternative approach for evaluating welfare risks, if possible; and d) to combine the ecological and welfare rankings of relative risk into a single aggregate ranking that could then be compared with the human health rankings.

2.3 Format of this Report

In addition to an Executive Summary, an Introduction, and a list of cited References, this report contains five major sections.

Section 3.0, Environmental Problem Areas, represents a further aggregation of the programmatic areas into eight general areas of environmental problems. The Subcommittee members were unanimous in their dissatisfaction with the original EPA list of problem areas that mixed sources, receptors, media, and specific regulatory obligations. This categorization reflects EPA programmatic interests more than it provides a rational basis for evaluating environmental problems in the United States. In addition, it omitted some problems of ecological significance that were outside of EPA's regulatory purview.

As a first step beyond the 1986 procedures carried out by EPA, the Subcommittee examined the original 31 EPA categories of environmental problem areas. Some of these were combined when we felt there were no differences in ecological risk (e.g., municipal and industrial non-hazardous waste sites); others were added when an important ecological risk was not covered in the 1987 EPA report (e.g., alteration and disturbance of terrestrial habitats). The second step was to combine the list of problem area categories into eight functional groups and to rank their relative impacts in terms of the potential severity of the hazard and spatial extent of effects.

Section 4.0, Ecological Risk Assessment Model, presents a very different model for producing ecological risk assessment. This approach follows that developed by Harwell and Kelly (1986), which was included in Appendix III of the Unfinished Business report. This model starts with the basic scientific understanding of stress agents and ecological responses across the variety of anthropogenic activities affecting the ecological systems of the United States. Several different scenarios of risk rankings were investigated. These included the rankings based on scale of stress (ecosystem, regional, biosphere), the transport media (air, water, or terrestrial), and the ecological recovery time (years, decades, centuries, or nonrecovery time). These detailed rankings provided the basis for a summary ranking of environmental stresses with respect to ecological risk.

Section 5.0, Welfare Risk Analysis, critiques the "Appendix IV - Welfare Risk Assessment" and presents an alternative paradigm. Four classes of welfare impacts were identified: Ecologically Mediated; Resource Sustainability; Direct Effects - Economic; and Direct Effects - Non-economic. Rankings were produced for three of these classes of welfare effects. The "Direct Effects - Economic" category requires specific economic data that were not available to the Subcommittee. Thus, no attempt was made by the Subcommittee to develop an economic ranking. A summary of welfare risk rankings combining the aspects of the other three categories was developed.

Section 6.0, Updates on Risk Categories, contains critiques of the problem areas, providing additional information to update these topics.

Section 7.0, Recommendations and Conclusions, presents six major recommendations developed by the Subcommittee to assist the Agency's capability to assess environmental risks.

3.0 ENVIRONMENTAL PROBLEM AREAS

3.1 Limitations of EPA List of Environmental Problem Areas

The Subcommittee was asked to address the EPA-specified list of the thirty-one environmental problem areas (initially developed for the EPA Comparative Risk Project - see Table III, page 10) in order for its results to be comparable with other evaluations (i.e., Human Health and Strategic Options Subcommittees). However, it was clear to the Subcommittee that the listed problem areas were not categorized in parallel, and that the criteria for selecting the items on the list were not primarily related to potential types of environmental stresses. Specifically, these listed problem areas are much more attuned to programmatic considerations within EPA than they are to actual environmental problems in the real world. For instance, waste sites are separated into four categories (active hazardous sites, inactive hazardous Superfund sites, non-hazardous municipal sites, and non-hazardous industrial sites); each category is divided based more on how they are regulated within EPA than on the types of stresses they may impose on the environment. Furthermore, the EPA list of problem areas is inconsistent with respect to the level of resolution of the classification. For example, one category includes all inputs to estuaries, coastal waters, and oceans from all sources, whereas another category consists only of accidental releases from oil spills.

Consequently, individual categories of the thirty-one environmental problem areas often contained many different types of environmental stresses. For example, EPA Environmental Problem Area 1 includes "criteria pollutants", i.e., those pollutants identified in the Clean Air Act for which National Ambient Air Quality Standards (NAAQS) are required (specifically, sulfur dioxide, nitrogen oxides, ozone, carbon monoxide, lead, and particulates). The types of ecological stresses associated with this single category vary widely, from local-scale deposition of a heavy metal, for which the primary concern is ecological routes to humans, to the transboundary-scale problem of acid deposition, which has the potential for significant ecological effects on freshwater and terrestrial ecosystems involving pH stress, aluminum

Table III - Original EPA List of Environmental Problems

1 - Criteria air pollutants from mobile & stationary sources; acid deposition
2 - Hazardous/toxic air pollutants
3 - Other air pollutants, (e.g., flourides, total reduced sulfur)
4 - Radon (indoor pollution only)
5 - Indoor air pollution (other than radon)
6 - Radiation (other than radon)
7 - Substances suspected of depleting stratospheric ozone layer
8 - Carbon dioxide and global warming
9 - Direct point-source discharges to surface waters - industrial sources
10 - Indirect point-source discharges to surface waters - POTW's
11 - Non-point source discharges to surface water plus in-place toxics in sediments
12 - Contaminated sludge (includes municipal and scrubber sludges)
13 - Discharges to estuaries, coastal waters, and oceans from all sources
14 - Discharges to wetlands from all sources
15 - Drinking water at the tap (includes chemicals, lead from pipe, biological contaminants, radiation, etc)
16 - Active hazardous waste sites (includes hazardous waste tanks, inputs to groundwater and other media)
17 - Inactive hazardous waste sites (includes Superfund, inputs to groundwater and other media)
18 - Municipal non-hazardous waste sites (inputs to groundwater & other media)
19 - Industrial non-hazardous waste sites (includes utilities)
20 - Mining wastes (e.g., oil and gas extraction wastes)
21 - Accidental releases of toxics (all media)
22 - Accidental releases from oil spills
23 - Releases from storage tanks (includes product & petroleum tanks)
24 - Other groundwater contamination (septic tanks, road salt, injection wells)
25 - Pesticide residues on food eaten by humans or wildlife
26 - Application of pesticides (includes risk to pesticide workers as consumers who apply pesticides)
27 - Other pesticide risks (leaching, run-off, air deposition from spraying)
28 - New toxic chemicals
29 - Biotechnology (environmental releases of genetically altered organisms)
30 - Consumer product exposure
31 - Worker exposure to chemicals

<u>Modified from:</u> EPA Report "Unfinished Business: A Comparative Assessment of Environmental Problems" pages 10-11. (EPA, 1987a).

toxicity, changes in redox potential, enhanced susceptibility to disease and pest infestations, differential effects on competitive interactions in ecological communities, and a host of other problems. Thus, the relative risks to the environment from this single category would entail an amalgamation of quite disparate stresses, spanning: a) many spatial scales of the extent of exposure; b) many different levels of hazard to ecological systems, and c) many different modes of action for toxicity or other impacts on ecological systems. It is inappropriate to assign a single level of risk to such a diversity of environmental stresses. Moreover, a single value assigned to such a broad category of stresses does not provide the decision-maker with information on the relative importance of the diversity of stresses within the category, unnecessarily losing much useful information that could be derived from the environmental risk ranking process.

Another difficulty with the EPA problem area classification is that many individual types of environmental stresses from anthropogenic activities were categorized into more than one of the thirty-one environmental problem areas. As one example, the potential ecological impacts from xenobiotic organic chemicals that are toxic to biota could be associated with the EPA-listed environmental problem areas 1, 2, 3, 9, 10, 11, 12, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 27, and 28 (see Table III, page 10). Because of this considerable degree of redundancy for a single type of environmental stress across the EPA categories of environmental problem areas, relative ranking of environmental risks would be impossible without knowing the relative distribution across the problem areas of the magnitudes of the stress. Following the same example, if it were determined that xenobiotic organic chemicals are a major risk to the environment, do all nineteen of the above listed problem areas rank high?

We decided that alternate approaches to environmental risk ranking are required. Two tacks were taken: 1) aggregation of related EPA environmental problem areas into a more limited number of categories, followed by ranking of those categories based on Subcommittee-developed criteria; and 2) disaggregation of the initial EPA environmental problem areas, with addition of other stresses of concern, into environmentally-relevant categories of stresses, followed by ranking of the new categories based on Subcommittee-developed criteria. The first approach, discussed in the following sections, has the advantage of being directly related to the EPA list being considered by the Human Health and Strategic Options Subcommittees. The second approach, detailed in Chapter 4, has the advantage of allowing examination of relative risk rankings established with regard to spatial scale, transport media, or other criteria, thereby preserving the considerable information and expertise used to evaluate environmental risks.

3.2 Ranking of Aggregated Environmental Problem Areas

Although the ranking in the Unfinished Business report was provided for all of the thirty-one problem areas, it appears that the differentiation in the ranking among various problem areas was not clearly substantiated. Consequently, the Subcommittee aggregated the problem areas into groups based on the following considerations:

a) the spatial extent of the area subjected to the stress;
b) the importance of the ecosystem that is actually affected within the stressed area;
c) the potential for the problem to cause ecological effects and the ecological response;
d) the intensity of exposure; and
e) the temporal dimension of both effects and the potential ecological recovery.

Factors a) and b) were classified as global, regional, or local in scale. A higher priority was given to areas under the global classification. Factor c) was classified as either high, medium, low, or unknown. Finally, factors d) and e) were classified as high, medium, or low. For both factors c) and d), a higher priority was given to problem areas that were classified as high. The classification of the problem areas according to the above factors is given in Table IV (see page 13). The rationale for the grouping of problem areas is given below, with the original number of the related EPA environmental problem in parentheses. Note that some problem areas (4,5,6,15,24,26,30 and 31) are not included since we did not consider them ecologically significant.

3.2.1 Air Quality (Environmental Problems 1-3,7,8)

Although one might be tempted to separate global warming (8) and stratospheric ozone (7) from criteria air pollutants (1) and hazardous air pollutants (2), the fact remains that all of the

Table IV - Classification of Problem Areas Relative to Size, Hazard, and Exposure

Aggregated Problem Areas	Original Problem Areas[a]	Size	Hazard[b]	Exposure
Air Quality	1,2,3,7,8	Global	High	High
Surface Water	9,10,11,20	Glob/Reg	High	High
Soil	12,25,27	Regional	High	High
Phys. Alteration	13,14,20	Local	Low-Hi	N/A
Groundwater	23,29	Local	Low	Low
Waste Sites	16,17,18,19	Local	Low	Low
Accident. Release	21,22	Local	?	Low/Hi
New Chemicals & New Technology	28,29	?	?	?

[a] This column lists the original problem areas as numbered in the "Unfinished Business Document: A Comparative Assessment of Environmental Problems". Note that problem areas 4,5,6,15,24,26, 30 and 31 were not considered as having an ecological impact.

[b] Defined as the inherent ability to cause harm.

N/A = Not applicable for this problem area

? = Unknown

above are closely linked to emissions (3) from chemical processes, energy generation, and non-stationary sources. For example, hydrocarbons play an important part in the generation of atmospheric ozone and hydrogen peroxide as well as the generation of sulfates and, thus, acid rain. Burning of fossil fuels leads not only to the increase in carbon dioxide levels that affect global warming but also to the emission of non-methane hydrocarbons that play an important role in controlling the levels of criteria pollutants. Thus, from the point of view of sources, air quality is a rational grouping that encompasses problem areas 1,2,3,7,& 8.

3.2.2 Surface Water (Environmental Problems 9-11,20)

Environmental problem areas 9-11 include direct (9) and indirect (10) point and non-point (11) discharges to surface waters. Problem area 20 (mining wastes) can also be considered as a potential contributor to surface water contamination. Thus, areas 9-11 and a component of area 20 are best grouped under the surface water category.

3.2.3 Soil (Environmental Problems 12,25,26)

Problem areas 25 and 26 consider pesticides. Since pesticides are applied onto the soil environment, the direct effect is on soil and vegetation. Subsequently, the movement and accumulation of pesticides through the food chain are important, and there can be a significant effect on wildlife. Contaminated sludge that is disposed of or treated in the soil environment leads to a direct contamination of the soil environment and subsequent migration to other systems (e.g., groundwater). Thus, from the viewpoint of the environmental medium that is directly affected, Items 12, 25, and 26 should be classified as a single category.

3.2.4 Habitat Alterations (Environmental Problems 13,14,20)

Environmental problem areas 13 and 14 consider the physical alteration of aquatic habitats and are therefore grouped together. Problem area 20, which is concerned with mining wastes, could be partially in this category given that mining activities and mining waste can lead to physical habitat alteration. Thus, regardless of the affected media, habitat alteration should be considered as a single group.

3.2.5 Groundwater (Environmental Problems 23,29)

Problem areas 23 and 29 consider release from storage tanks and other groundwater contamination sources. Since groundwater protection is the focus, groundwater should be the category of concern.

3.2.6 Waste Sites (Environmental Problem Areas 16-19)

Environmental problem areas 16-19 involve various types of waste sites and, thus, should be grouped under the same category.

3.2.7 Accidental Releases (Environmental Problem Areas 21,22)

Accidental releases of toxics (21) and oil spills (22) are both in the category of accidental releases and should be considered under the same class.

3.2.8 New Chemicals and New Technology (Environmental Problem Areas 28,29)

Biotechnology (29) and the category of new chemicals (28) represent new ventures that are designed for the introduction of new materials or chemicals. Since there is a lack of information regarding the potential effects from these unknown sources of potential contaminants, problem areas 28 and 29 are grouped into a single problem area. It is important to note that although this area was ranked lowest in priority, this was largely because of the lack of knowledge about this potential future problem area which at present hinders a rational ranking. However, in order to minimize future pollution problems, an effort must be maintained to identify potential ecological impacts that may be associated with new chemicals and processes whether chemical or biological.

4.0 ALTERNATIVE MODEL

4.1 Summary of the Disaggregation Approach

The second approach that the Subcommittee used to improve the environmental risk assessment methodology involved the disaggregation of the EPA environmental problem areas into environmentally relevant stresses. The Subcommittee decided to adopt the approach developed by the original panel of outside ecological experts convened during the initial EPA Comparative Risk Project. This panel met in October, 1986, and prepared a separate report (Harwell and Kelly, 1986; also included in Appendix III of the "Unfinished Business" Report (EPA, 1987b)) that detailed a methodology for ecological risk ranking. Specifically, that original panel: 1) considered the EPA list of thirty-one problem areas and eliminated areas with no ecological relevance (e.g., Problem Area 4, indoor exposure to radon); 2) identified and categorized specific types of environmental stresses associated with each environmental problem area on the EPA list; 3) identified additional environmental stresses that were not included in the EPA list, including items that may not presently be within EPA purview for regulation or management; 4) developed a list of ecological systems categorized with respect to the nature of stress responses or recovery; 5) developed a matrix of environmental stresses versus ecosystem types, with each cell in the matrix containing an evaluation of the potential and magnitude of ecological effects and recovery; and 6) utilizing this matrix and a set of panel-developed criteria discussed below, ranked the list of environmental stresses with respect to potential environmental risks.

The present Subcommittee adapted the previous panel's methodology as follows: 1) modified the panel's list of environmental stresses with minor wording changes in the names of a few categories (e.g., substitution of hazardous in place of toxic) and the addition of one category (species depletion); 2) reevaluated the potential ecological risk from each environmental stress (differentiated across scales of stress [local to global]) and modified the similar matrix from the previous panel's report, with attention to new information or understanding not available at the time of the 1986 deliberations; 3) developed a new matrix of ecological risks of the environmental stresses differentiated by transport medium (air, water, and terrestrial); and 4) collapsed these two ecological risk matrices into a synthesis ranking of relative ecological risks from environmental stresses.

4.2 List of Environmental Stresses Considered by the Subcommittee

The Subcommittee began with the list of environmental stresses presented in Harwell and Kelly (1986). The list was reconsidered with respect to the need for wording changes as well as any missing environmental stresses that should be added. A revised list was prepared by the Subcommittee; this list can be directly related to the original EPA list of thirty-one problem areas using the matrix in Table V (see page 18). This matrix indicates those environmental stresses that were not included in the EPA list of problem areas, as well as a few problem areas that had been combined by EPA in the Unfinished Business Report. The matrix also separates the environmental stress agents by source.

4.3 Ecological Risk Evaluations

4.3.1 Ecosystem/Stress Response Matrix

The panel of ecological experts convened in 1986 (Harwell and Kelly, 1986) categorized ecosystems of interest into ecosystem types based on the potential for differences in ecosystem responses or recovery from stress. This list of ecosystem types was accepted by the Subcommittee without revision (Table VI, see page 19).

The potential for ecological effects from each environmental stress were estimated by the original panel of experts using the following factors (Harwell and Kelly, 1986):

1) The potential intensity of ecological effects, evaluated as high, medium, low, or no effect; this expert judgment estimation was based in part on the background information provided by EPA to the panel, but was primarily based on the expertise and experience of the ecological panel.

2) The nature of the ecological effect from each specific environmental stress, categorized as: a) potential effects on biotic community structure, such as alterations in the trophic structure, changes in species diversity or richness, or other

Table V - Ecological Risk Matrix

STRESS AGENTS

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	N.L.
AIR SOURCES																																
gaseous phytotoxicants	■	■																														
acid deposition	■																															
air dep. - organics & metals	■	■	■																		■							■				
greenhouse gases								■																								
ozone-depleting gases							■																									
WATER SOURCES																																
hazardous organics									■	■	■	■									■	■						■				
pesticides, herbicides																					■				■		■					
chlorination products									■	■																						
hazardous inorganics									■	■	■	■								■	■							■				
nutrients, BOD									■	■	■	■								■												
microbes									■	■		■																				
turbidity									■	■	■									■												
acids									■	■						■	■			■	■											
thermal pollution									■	■																						■
entrainment/impingement																																■
oil & petroleum products									■	■	■									■		■										
TERRESTRIAL SOURCES																																
pesticides and herbicides																					■				■		■					
solid matter												■						■	■	■												
hazardous org. & inorg.												■				■	■	■	■	■	■	■						■				
microbes												■																				
OTHER ENVIRONMENTAL PROBLEMS																																
radionuclides		■				■														■	■											
habitat alteration													■	■						■												■
introduced species																																■
biotechnology																													■			
groundwater contamination												■				■	■	■	■	■			■	■	■		■	■				
species depletion																																■

Adapted from Harwell and Kelly (1986)

Numbers refer to Original EPA Problem Areas

N.L. - Not Listed in original EPA Unfinished Business Report

Table VI - List of Ecosystem Types

Freshwater Ecosystems	Marine and Estuarine Ecosystems
- buffered lakes	- coastal ecosystems
- unbuffered lakes	- open ocean ecosystems
- buffered streams	- estuaries
- unbuffered streams	
Terrestrial Ecosystems	**Wetland Ecosystems**
- coniferous forests	- buffered freshwater isolated wetlands
- deciduous forests	- unbuffered freshwater isolated wetlands
- grassland ecosystems	- freshwater flowing wetlands
- desert & semi-arid ecosystems	- saltwater wetlands
- alpine and tundra ecosystems	

community-level indicators of disturbance; b) potential effects on ecological processes, such as changes in rates of primary production, nutrient cycling, decomposition, and other important ecological processes; c) potential effects on individual species of particular direct importance to humans, e.g., species with particular aesthetic or economic value, or endangered or threatened species; and d) the potential for the ecosystem to function as a vector for routes of exposure to humans of chemicals or organisms having potential health-effects concerns.

3) The degree of certainty associated with these estimations, differentiating those circumstances where the data and understanding are sufficient for certain or probable projections to be made versus the situation of either poorly understood stress-response relationships or of highly infrequent occurrence of adverse responses; and

4) The probable time scale for recovery to occur following cessation of the stress, estimated as years, decades, centuries, or indefinite time for recovery.

In the original ecological panel's ranking, a matrix of the environmental stress agents versus ecosystem types was developed with expert judgment on each of these four factors (intensity of potential effects, type of ecological response, uncertainties about the estimate, and time scale for ecological recovery) (Table 4 in Harwell and Kelly, 1986). The present Subcommittee did not reexamine every element in this matrix. Rather, the Subcommittee examined the summary ranking (Table 7 in Appendix III of the "Unfinished Business" Report) of the ecological stresses divided by spatial scale that was developed based on the detailed ecosystem/stress matrix. The Subcommittee evaluated these rankings with respect to whether or not the Subcommittee agreed with the existing ranking, or if new information or understanding should result in changes to the ranking. The Subcommittee also expanded the ranking to include a category of low-impact effects (not included in the original summary ranking).

4.3.2 Environmental Stress Rankings by Scale

The results of the reevaluation by the Subcommittee are presented in Table VII (see page 21). This matrix of rankings separates the relative ecological importance of each environmental stress by the scale of the stresses (biosphere/global; regional; or ecosystem/local). The Subcommittee changed this stress matrix only modestly compared to the initial summary ranking in the 1986 report. Specific changes to be noted include: 1) elevating the issue of depletion of stratospheric ozone from CFCs and other anthropogenic chemicals from the category of "unknown but potentially very important" to the category of "high ecological effects"; this elevation of concern is because of the acquisition in the intervening three years of considerable information about stratospheric ozone depletion in response to CFCs, including evidence, from data from Antarctica, of exceptionally intense ozone hole development in the austral springs of 1987 and 1989; 2) addition of depletion of biotic resources to the "high" category for regional scales because of an enhanced concern for large-scale human activities such as tropical deforestation; 3) decreasing the importance of oil and petroleum products at the ecosystem level from "high" to "medium ecological importance" to reflect a moderated concern about the ecological effects of oil inputs to the environment; 4) addition of the category of "low ecological importance", to which were added stresses of radionuclides, solid wastes, and thermal pollution; this addition was done to indicate

Table VII - Ranking of Ecological Risks Characterized by Scale of Stress [a]

Ecological Risk (↑ Increasing Ecological Risk)	Biosphere (← Increasing Scale of Stress)	Regional	Ecosystem (local)
High (3 Levels of High Ecological Risk are Identified)	Global Climate Stratospheric Ozone	Global Climate Stratospheric Ozone Habitat Alteration	Global Climate Stratospheric Ozone Habitat Alteration Biological Depletion (*)
	Habitat Alteration	Airborne Toxics Biological Depletion (*)	Airborne Toxics Toxics in Surface Waters Pesticides/Herbicides
		Acid Deposition	Acid Deposition Nutrients Acid Inputs to Surface Waters
Medium	Airborne Toxics	Toxics in Surface Waters Herbicides/Pesticides	BOD Turbidity Oil
Low		Oil Spills Groundwater Contamination	Radionuclides Chlorination Thermal Pollution Groundwater Contamination
In some cases, high risk		Deliberate Release of Genetically Engineered Organisms Introduced Species (*)	Deliberate Release of Genetically Engineered Organisms Introduced Species (*)

[a] Those problem areas not listed in each column were deemed not to be ecologically significant at that scale.
(*) Refers to problem areas not originally listed by EPA.

that these issues, while of limited concern ecologically, are nevertheless not completely free of potential for adverse ecological effects; 5) changing the issues of groundwater contamination and chlorination products from the "unknown" category to the "low ecological effects" category, based on better understanding of these issues by the Subcommittee members than by the original panel; and 6) adding the globally transported airborne toxics to the global-scale "medium ecological importance" category.

In addition to these modifications, the Subcommittee subdivided the previous "high ecological importance" category into three subcategories to reflect a differentiation in the level of concern about the environmental stresses in the high category. Consequently six rankings exist in the Subcommittee's final scheme (Table VIII, see page 23): **HHH** for highest potential ecological risk, **HH** for next highest ecological risk, **H** for high ecological risk, **M** for medium ecological risk, **L** for low ecological risk, plus a category of "in some cases high risk" effects. The latter category was established to cover environmental issues such as the deliberate release of genetically engineered organisms, in which most inputs to the environment would likely have little or no effect, but the potential exists for some types of inputs to have very important effects; environmental stresses in this category would require case-by-case evaluation to determine potential risks to the environment.

4.3.3 Environmental Stress Rankings by Medium

The Subcommittee also considered the relative importance of ecological effects of the environmental stresses, separated by transport media (air, water, or terrestrial). That is, the ecological risk ranking by spatial scale, discussed above, was next examined with attention to the medium of transport of the stress agent rather than by spatial scale. A new matrix of ecological risk rankings (Table IX, see page 24) was prepared by the Subcommittee, with the same elements as in the previous matrix. This provides information about the relative ecological risks that may be relevant to major divisions within EPA.

4.3.4 Ecological Recovery Times

The ranking of potential effects on ecosystems from the ecological stresses included attention to the issue of recovery

Table VIII - Summary of Ecological Risk Rankings[a] (Taken from Tables VII, IX and X)

Environmental Stress	Extent of Stress			Media			Recovery Time		
	Biosphere	Regional	Ecosystem	Air	Water	Terrestrial	Short	Medium	Long
1. Global Climate	HHH	HHH	HHH	HHH					X
Habitat Alteration	HH	HHH	HHH		HHH	HHH		X	X
Stratospheric Ozone	HHH	HHH	HHH	HHH					X
Biological Depletion (*)		HH	HHH		HH	HH			X
2. Herbicides/Pesticides		M	HH	HH	HH[c]			X	
3. Toxics in Surface Waters		M	HH		HH[c]			X	
Acid Deposition		H	H	H				X	
Airborne Toxics	M	HH	HH	HH[b]				X	
4. Nutrients			H		H		X		
BOD			M		M		X		
Turbidity			M		M		X		
5. Oil		L	M		M	L	X		
Groundwater		L	L		L				X
6. Radionuclides			L	L	L			X	
Acid Inputs to Surface Waters			H		H			X	
Thermal Pollution (*)			L		L		X		

KEY: HHH › HH › H › M › L - Where HHH = HIGHEST; HH = HIGHER; H = HIGH; M = MEDIUM; L = LOW

* Refers to problem areas not originally listed by EPA.

[a] Those problem areas not listed in each column were deemed not ecologically significant for that category.

[b] This is for regional/local transport; for global transport, the ranking is Medium.

[c] This is for local effects; for regional effects, the ranking is Medium.

Table IX - Ranking of Ecological Risks Characterized by Medium[a]

Ecological Risk	Air	Water	Terrestrial
High	Global Climate Stratospheric Ozone	Habitat Alteration	Habitat Alteration
	Regional/Local Transport Airborne Toxics Pesticides/Herbicides	Biological Depletion (*) Toxics (local) Pesticides and Herbicides (local)	Biological Depletion (*)
(3 Levels of High Ecological Risk are identified)	Acid Deposition	Nutrients Acid Inputs	
Medium	Global Transport Airborne Toxics	Oil BOD Toxics (regional) Turbidity Herbicides/Pesticides (regional)	
Low	Radionuclides	Radionuclides Thermal Pollution Chlorination Groundwater Contamination	Oil Spills
In some cases, high risk	Deliberate Release of Genetically Engineered Organisms	Deliberate Release of Genetically Engineered Organisms Introduced Species (*)	Deliberate Release of Genetically Engineered Organisms Introduced Species (*)

Increasing Ecological Risk ↑

a Those problem areas not listed in each column were deemed not to be ecologically significant in that medium.
(*) Refers to problem areas not originally listed by EPA.

times. If a stress was considered to cause a very long-term effect on an ecosystem, then it would be ranked higher than a stress to which the ecosystem could recover more rapidly. The Subcommittee decided that this information, if made more explicit, would be useful to decision makers in evaluating policy options, especially if combined with an estimate of the time scales that could be involved in implementing options. Consequently, an ecological risk ranking matrix was developed by the Subcommittee that indicates the time for ecological recovery upon elimination of the stress (Table X, see page 26). This primarily relates to intrinsic time scales of ecological and biogeochemical systems. For, instance, a long time for recovery from habitat alteration is indicated, as major changes to habitat structures like soils or mature tree stands require considerable time for the system to be reestablished at a former state. Other time lags for restoration of the environment relate more to the societal delays in implementing control options as well as the time for the stress to be eliminated once the option was implemented. For example, there may be a delay in recovery from stratospheric ozone depletion effects, in part because the residence times in the atmosphere of some CFCs may be a century or longer, so that controls implemented immediately may not become effective for decades, and in part because of delays in eliminating CFC production and emissions in all countries around the world. The combination of these factors (time lags intrinsic to stresses involving physical systems, time lags intrinsic to ecological responses to stress, and time lags for implementation of societal controls) provides a rough estimate of the time scales that could be involved in addressing and solving each particular ecological stress.

4.4 Summary of Ecological Risks

The final ecological risk ranking prepared by the Subcommittee is a synthesis of the above matrices. This ranking is provided (Table VIII, see page 23) to give a single list of the environmental stresses, numbered in order of decreasing potential ecological risks. The synthesis rankings were derived qualitatively using expert judgment rather than a numerical metric based on the more detailed risk matrices discussed previously, as the Subcommittee decided that any specific quantitative or semi-quantitative methodology for combining risks assigned across scales and media (e.g., adding the total number of cells with H designations for each stress) would not be not defensible with

Table X - Time for Ecological Recovery

Increasing Recovery Time →

Increasing Risk ↑	Environmental Stress	Short (Years)	Medium (Decades)	Long (Centuries)
	1. Global Climate			X
	Habitat Alteration		X	X
	Stratospheric Ozone			X
	Biological Depletion			X
	2. Herbicides/Pesticides		X	
	3. Toxics in Surface Waters		X	
	Acid Deposition		X	
	Airborne Toxics		X	
	4. Nutrients	X		
	BOD	X		
	Turbidity	X		
	5. Oil	X		
	Groundwater			X
	6. Radionuclides		X	
	Acid Inputs to Surface Waters		X	
	Solid Wastes	X		
	Thermal Pollution	X		
In some cases, High Risk:	Deliberate Release of Genetically-engineered organisms	X	X	X
	Introduced Species		X	X

present ecological risk assessment capabilities. However, the synthesis ranking developed by the Subcommittee is not arbitrary, but, rather, is based on criteria of the intensity, magnitude, duration, and recovery prospects for each stress. The Subcommittee feels strongly that a concerted and continuous effort by the Agency to improve ecological risk assessment methodologies is warranted.

The synthesis ranking in Table VIII (see page 23) represents the consensus of the Subcommittee and illustrates the increased concern given by the Subcommittee to those issues of largest potential spatial extent and longest potential recovery times. Consequently, the environmental issues of global climate change, habitat alteration, stratospheric ozone depletion, and biological depletion are ranked very high, because of the pervasive extent of these environmental stresses and the diversity of resultant impacts on ecological systems at species, community, and process levels. It is notable that not until the middle grouping of environmental stresses (2 and 3) do toxic chemical stresses become ranked with respect to ecological risks. It should also be noted that for rankings 3-6, more than one environmental stress is listed, as the Subcommittee could not distinguish the ecological risks among the stresses listed within a single number category. The last category, high risks in some cases, is not ranked numerically, as the potential exists in infrequent occasions for these stresses to cause significant adverse ecological effects if improperly regulated, but under other circumstances these stresses may cause essentially no ecological effects.

Finally, the Subcommittee recognizes that the highest ranked ecological risks do not reflect the present emphasis within EPA and, indeed, include some aspects not presently within the legislative mandate of the Agency (especially issues of habitat alteration, for which EPA's role is mostly limited to wetlands ecosystems). Nevertheless, the Subcommittee believes the synthesis ranking of ecological risks represents the ecological issues of greatest potential danger to the environment of the United States and of the Earth.

5.0 WELFARE RISK ANALYSIS

5.1 Background

The Subcommittee was charged with three specific tasks regarding welfare risks: 1) evaluate Appendix IV of the Unfinished Business Report (EPA, 1987c) entitled "Welfare Risk Work Group"; 2) develop a welfare risk evaluation paradigm that is compatible with the ecological risk evaluation system; and 3) combine the ecological and welfare rankings into a combined priority array.

The Subcommittee is composed of environmental chemists and ecologists. There are no economists on the Subcommittee, although several were consulted. In the Subcommittees view, we cannot engineer the time lags in the geochemical and ecological feed-back loops. Economic analyses should always reflect a planning horizon long enough to capture all effects of the issue under study. For ecological issues, the time frame may have to extend for hundreds of years and many generations of humans. If one wishes to combine ecological and welfare impacts into an aggregate priority ranking system, the methodology currently being utilized by the Agency to quantify economic impacts <u>must</u> be modified to resolve this discontinuity.

5.2 Subcommittee Findings

The Subcommittee finds: a) that the EPA's welfare effects analysis contained in Appendix IV, Welfare Risk Work Group of Unfinished Business (EPA, 1987c), was defined too narrowly within the array of possible analytical alternatives and was too limited to economics; b) that many of the assumptions of the economic analyses used by EPA give insufficient attention to the current state of scientific understanding; and c) that some of the details of the economic analyses presented in the Unfinished Business document were incomplete or inappropriate for addressing environmental problems.

The Subcommittee began the welfare ranking evaluation by redefining welfare effects to be <u>all effects on humans and societies, excluding human health effects, that may result from</u>

environmental problems. Thus, welfare risk was expanded to include all aspects of the quality of human life as interacting with the environment. These welfare effects may be indirect or direct. Indirect welfare effects include those effects mediated by ecological systems; i.e., effects on humans caused by changes to the natural environment. These ecologically-mediated effects may be further divided into impacts that involve irreversible alterations to the environment, and therefore, fundamentally affect resource sustainability (e.g., loss of biodiversity, depletion of soils, elimination of habitats), and those alterations that are not permanent but, nevertheless, have an impact on parts of the environment that humans care about (e.g., reduction in fisheries, eutrophication of lakes, reduced growth of commercial trees). Direct welfare effects include those that have direct economic importance (e.g., building damage from acid deposition) and those that are non-economic (e.g., presence of excessive noise or odors, reduced visibility, or other reductions in the quality of life).

The Subcommittee finds that the ranking for ecological risks discussed previously and for welfare risks associated with ecologically-mediated impacts are essentially the same. The welfare risks associated with sustainable resources were evaluated by the Subcommittee. The welfare risk ranking for direct economic effects was not developed by the Subcommittee because of insufficient data. The ability of science to contribute to the ranking of non-economic effects is still developing and the Subcommittee made an initial attempt at this ranking. Finally, the Subcommittee developed an overall welfare risk ranking scheme considering all four aspects of welfare risks.

5.2.1 Critique of Appendix IV

The welfare effects analysis in Appendix IV (EPA, 1987c) was based on a very small amount of information that was available to the Agency. The analysts appeared to limit their concern to only a few of the services produced by ecosystems, and ignored the more complex and long-term interconnectedness of all living things on earth. It is imperative that the Agency adopt a broader and more inclusive view of ecosystem services and work to integrate this view with economic analyses of environmental problems.

5.2.2 Sustainability

It has long been recognized that short-term profit maximization is a misguided objective. Economic analyses of environmental issues must take a long-term view with the ultimate goal of sustaining life supporting ecosystem functions. In the long run, irreversible resource damage will undermine the sustainability of the ecosystem and therefore, the quality of life and the sustainability of human society itself.

The procedure of "...ranking future effects lower than present, all else being held constant" (page 1-2, EPA, 1987c), is not scientifically sound for ecological risks. There are several compelling reasons why the economic discounting theory is inappropriate for ecological issues. First, the concept of discounting values of ecological resources at some fractional rate per year is inconsistent with the "stewardship responsibilities" (page 6-10, EPA, 1937c) emanating from the public trust doctrine approach to most environmental legislation.

The concept and application of discounting needs further examination. In particular, use of positive discount rates has serious implications for intergenerational equity when applied to long-time frame problems. Recognizing the inability of future generations to "vote" in current capital markets and influence interest rates, suggests that this is more than an economic problem. We need to address the scientific and ethical issues associated with "sustainable" social activity. For inter-generational issues it may be appropriate to adopt a zero discount rate.

Moreover, discounting future environmental problems greatly devalues the importance of large-scale and long-term environmental problems. Ecological systems have intrinsic time lags, such that the adverse response from a stress is delayed to the future. This is a basic characteristic of ecosystems that must be central to an ecological risk assessment paradigm. For example, applying the discounting theory to the issue of global climate change led the EPA welfare report to treat this as a medium level problem because the effects would not be felt until the middle of the next century. Yet desirable and effective control and mitigation activities for climate change effects must begin much sooner, because of the inherent time lags in global responses. The costs of mitigation are usually not constant over time, often increasing geometrically because of the spatial dimensionality of the transport mechanisms.

Finally, the applications of discount rates to costs and benefits associated with the environment incorrectly implies that ecological services can be readily exchanged, both now and in the future, as fundable commodities. Ecological resources provide streams of benefits over time, and may therefore, be considered environmental capital analogous to physical capital (e.g., equipment and technology) and human capital (e.g., knowledge and skills). Environmental capital and the life-support services it provides, are not, however, necessarily substitutable for other forms of capital, and should not be discouraged as if they could be bought or sold like machinery or housing.

5.2.3 Willingness to Pay

Most economic techniques employed in environmental assessments, management, and policy formulation are based on the assumption that individuals' tastes and preferences are the appropriate basis of economic value. This premise allows economists to use market prices, which reflect these preferences, to estimate value. When services provided by ecosystems are not traded on markets, economists use alternative criteria of value, such as individuals' stated or implied willingness to pay for the preservation of an ecosystem service (or willingness to accept compensation of its loss).

When it is applied to the valuation of ecosystem services, the assumption that value derives from individual preferences may be inconsistent with fundamental ecological principles. Individuals may enjoy the benefits of these services without any knowledge of their existence, thus their preferences may imply values that do not reflect the ecological importance of natural systems and the services they provide to humans.

In addition, value criteria may be problematic. The use of willingness to pay implies that values assigned by an individual are constrained by his or her affluence. This may be inconsistent with property rights vested in public trusteeship and with public rights of access to unimpaired natural resources reflected in Federal statutes: An Environmental Bill of Rights.

The basic "services" provided by the ecosystem, including supply of clean air and water, food chain maintenance, weather control, provision of genetic diversity, etc., represent the support system that all humans depend on. These resources need to be protected from overexploitation. Yet in managing the ecosystem as scarce resources, too much emphasis has been placed on willingness-to-pay as inferred from individual actions or statements. We need to recognize that the services provided by the ecosystem are complex and long term. We need to develop more complete descriptions of the ecology-economics interface. Not all of these connections can be valued in dollar terms. Nevertheless, information about these connections and services need to be presented in a form appropriate for analysis by environmental decision makers. These representations may not fit into the traditional benefit-cost framework. Either that framework needs to be expanded, or the information should be presented in a manner parallel to the benefit-cost framework.

Furthermore, the reality of "willingness to pay" is usually not realized until the right to access is removed or seriously threatened. This is true in general for scarce resources, but presents a severe problem for environmental issues. By the point in time at which this is realized, it may be too late or excessively expensive to provide for the interconnectedness of the environmental response. Consequently, societal demands for the expenditure of funds to protect a threatened resource are much greater than to maintain an unthreatened one.

5.2.4 Multiplier Concept

Economic impact analyses normally include secondary impacts that affect the supporting economic infrastructure. When economic analyses are utilized to justify economic development, multipliers are standard procedures. If they are utilized on the development side of the analysis, they must be utilized on the environmental side as well. When the James River in Virginia was closed to commercial and recreational fishing because of Kepone contamination, the impacts included the losses to trucking companies, fishing lure manufacturers, outboard motor repair shops, etc. Thus, the real costs are far greater than the direct monetary value of the fish harvest. If economic analyses are included in welfare impact assessments, the real costs should be utilized to illustrate the true benefits of environmental stewardship. Then, the benefits of major control and mitigation efforts would more often exceed the costs of program implementation.

5.3 Welfare Risk Paradigm

We propose an alternative welfare impact classification scheme that is intellectually consistent with ecological functions and time scales. As defined above, the specific welfare impacts fall into four classes:

a) Ecological quality
b) Resource sustainability
c) Direct effects - economic
d) Direct effects - non-economic

These are discussed in further detail below (See also Table II, page 3).

5.3.1 Ecological Quality

This class of effects are indirect impacts on humans that result from a reduced quality of an environmental resource or decreased human utility, but which do not permanently impair the ecological structure and function of the resource. For example, sublethal concentrations of PCBs in Great Lakes salmon do not impair the growth, survivorship, or reproduction of the fish stocks. Yet a risk assessment action level of 2 ppm prohibits the sale of these fish in interstate commerce, and public concerns about these contaminants in fish adversely affect the sport-fishing industry. Similarly, the recent Exxon Valdez oil spill in Prince William Sound, Alaska, produced a reduction in the breeding populations of certain sea birds, sea otters, and intertidal organisms. But this is expected to be a temporary loss in resource that will not threaten the long-term integrity of the ecosystem. Sublethal accumulations of toxic substances and intermittent perturbations of the ecosystem structure and function characterize this category.

5.3.2 Resource Sustainability

This category of welfare impacts involve irreversible losses of ecosystem structure and functions. These can involve losses of critical habitats or species extinctions resulting from anthropogenic activities. Wetlands destruction, soil erosion, conversion of tropical rainforests to agriculture, and rising sea levels illustrate these types of impacts. Sustained acute- or chronic-exposure levels of toxic substances to critical classes of organisms can also impair ecosystem functions. Persistent non-point agricultural inputs of herbicides into surface waters could inhibit primary productivity. Increased UV-B radiation from a depleted stratospheric ozone layer could reduce algal productivity in marine ecosystems.

5.3.3 Direct Effects - Economics

This category involves direct physical changes that cause adverse economic impacts on humans (excluding human health effects). The monetary damages to stone structures resulting from acid rain, the loss in property value of houses with radon contamination, and loss of surface water contaminated by industrial effluents as an agricultural irrigation source are examples of direct physical effects that have a clear economic value. These are the effects that are usually included in environmental impact analyses.

5.3.4 Direct Effects - Non-Economic

This category of welfare effects primarily involves social nuisances. Odors, noise, and reduced visibility result from sensory modalities that affect the perception of quality of the environment but may or may not affect human health. The courts have upheld social nuisance cases as legitimate examples of welfare disbenefits. There are no generally accepted standards that define an acceptable environmental quality, but liability is determined on a case-by-case basis. Odors from animal feedlots, reduced visibility in certain urban areas, and noise from truck traffic on expressways are documented examples of these social perceptions.

5.4 Welfare Risk Rankings of the Subcommittee

The rankings for welfare effects are based on differing data bases. "Ecologically Mediated" welfare functions are based on impacts on basic population and ecosystem processes. Therefore, we determined that ecologically-mediated welfare risk rankings are identical to those produced for the ecological effects section.

The welfare risk effects associated with ecological sustainable issues involves impacts on the environment that are irreversible or of long duration compared to human perspectives. The Subcommittee considered time to recovery as an explicit component of the rankings which are presented in Table XI (see page 36).

The welfare function associated with the "Direct Effects - Economic" class of responses can be directly calculated by monetary damages. These data were not available to the Subcommittee, so no rankings were possible for this welfare risk category.

The "Direct Effects - Non-Economic" welfare effects were ranked by the Subcommittee using expert judgment, as no other analytical methodology presently exists. We agreed that negative impacts associated with sensory modalities (sound, sight, or smell) should be included. We held diverse opinions on whether and how human perceptions and feelings, such as fear, anxiety, and unrealized expectations, should be included.

The integrated welfare rankings are contained in Table XI (see page 36).

Table XI - Integrated Welfare Rankings[a]

RANKING	WELFARE ISSUE	RECOVERY TIME
HIGH:	Global Climate	L
	UV-B Ozone Depletion	L
	Habitat Alteration	L
	Biologic Endangered/Extinct	L
MEDIUM:	Acid Deposition	M
	Airborne Toxics	M
	Toxics in Surface Waters	M
	Pesticides and Herbicides	M
	Nutrients	
	Groundwater	M
LOW:	Acid Inputs to Surface Waters	
	BOD	
	Oil	
	Turbidity	
	Solid Waste (non-hazardous)	
	Radionuclides	
	Chlorination	
	Thermal Pollution	
IN SOME CASES, HIGH RISK:	Deliberate Release of Genetic Engineered Organisms	S
	Introduced Species	

[a] For Categories I, II, IV - Based on non-direct economic issues

Recovery Time is given as long-term, or centuries (L); medium-term, or decades (M); or short-term, or years (S).

6.0 UPDATES ON RISK CATEGORIES

The Subcommittee reviewed the original EPA list of environmental problems (Table III, see page 10)) with the goal of modifying the list if, in our view, the list was either incomplete or duplicative from an ecological risk perspective. We made the following modifications.

Problem areas 18 and 19, municipal and industrial non-hazardous waste sites, were combined. Our review of the literature led to the conclusion that the ecological impacts are not significantly different.

The original EPA list included only one type of habitat alteration, specifically areas 13 & 14, which dealt with discharges (alteration) to aquatic habitats. The Subcommittee believes that ecological impacts caused by alteration of terrestrial habitats are certainly as significant as alteration of aquatic habitats and should be considered in this report, even though regulation of activities that cause such alteration is not presently an EPA responsibility. The Subcommittee also considered habitat disturbance to be a potentially significant ecological impact. Even though not an irreversible physical alteration, habitat disturbance by human activities (e.g., overflights, human and dog access to beaches) can cause habitat abandonment or restricted use.

The Subcommittee added biological depletion to the list of environmental problem areas. This category includes depletion of natural populations because of over-harvesting as well as species extinction. Introduction of species was also added to the list, on the basis that exotic species may disrupt natural communities and ecosystems.

The Subcommittee reviewed the Background Papers written by EPA in 1987 and reevaluated them in light of more recent information. These background papers were prepared by EPA in order to provide additional insights concerning the environmental problem areas. These were included in Appendix III of Unfinished Business (EPA, 1987b). The following sections reflect the Subcommittee discussion of these environmental problem areas. EPA summarized its ranking of environmental problems areas into six groups, with Group 1 problems having the highest impact and Group 6 the lowest impact. The EPA group ranking and our adjective ranking are included in each section, generally at the end. Our rankings follow the scheme given in Table VIII on page 23: (e.g., HHH > HH > H > M > L) where HHH = Highest Risk; HH = Higher Risk; H = High Risk; M = Medium Risk; and L = Low Risk.

6.1 Criteria and Toxic Air Pollutants

The ecological impacts of ozone and acid deposition are well documented, and significant data bases on both the extent of ozone levels and acid deposition now exist (NAS, 1989; NAPAP, 1989; EPA, 1988). The overview of ozone and acid deposition provided in EPA (1987b) is detailed and represents a reasonable summary of the state of the art in 1986. Since then there have been a number of studies (e.g., NAPAP, 1987) that have suggested that hydrogen peroxide is also an oxidant that may lead to damage to trees. Gaseous hydrogen peroxide is formed by photochemical reactions in the atmosphere, and its chemistry is interlinked with that of ozone. In addition, the photochemical reactions of non-methane hydrocarbons (NMHC), nitrogen oxides, ozone, and hydrogen peroxide are linked and affect the atmospheric concentrations of nitrogen oxides, ozone, hydrogen peroxide, and the formation of airborne strong acids. Ozone and hydrogen peroxide are important oxidants that lead to the formation of nitric and sulfuric acids in rain and cloud droplets from precursor nitrogen oxides and sulfur dioxide.

The direct ecological risks of all toxic air pollutants on vegetative covers are not clearly established. However, there is little doubt that various toxic air pollutants can accumulate in plants and animals through the food chain (Travis and Arms, 1988). Thus, effects on wildlife from bioaccumulation may be particularly significant. It is possible that some toxic air pollutants may be precursors to chemicals that may be toxic to plants. However, much work is needed in this area in order to document exposures and elucidate uptake mechanisms and associated ecological effects.

Although toxic air pollutants were ranked by EPA as Group 4, some chlorinated hydrocarbons play an important role in atmospheric photochemistry. Thus, while one can argue that the important direct ecological stresses are ozone and acid rain, the factors controlling the generation of those stresses are closely linked and inseparable. Nitrogen oxides are also a factor in acid rain formation as well as visibility reduction. Since solar radiation is an important factor that affects the generation of ozone and hydrogen peroxide in the atmosphere, greenhouse gases and ozone can

affect solar radiation and in turn photochemical reactions. Thus, problem areas 1,2,7, and 8 are intertwined.

Our ranking of this issue varies with the scale considered. At ecosystem and regional levels, airborne toxics are high (HH) risk, but at the biosphere level, that risk drops to medium (M). Acid deposition is ranked at high (H) risk at both ecosystem and regional levels.

6.2 Radiation from Sources Other than Indoor Radon

This category includes environmental exposure to ionizing and non-ionizing radiation (beyond natural radiation). Increased radiation from stratospheric ozone depletion or medical exposures is not included here.

There have not been important changes in either the information base, risk assessment, or public perception concerning radiation hazards to ecological systems since publication of the Unfinished Business report. An extensive knowledge base, conservative standards, and a highly-regulated industry have reduced environmental risks. Nuclear industry practice is ALARA (as low as reasonably achievable) for high-level wastes, oftentimes well below regulatory guidelines.

The largest sources of radiation are natural cosmic and earth background radiations, followed by routine medical and diagnostic exposures to humans but not the environment. Anthropogenic environmental exposures primarily result from residual weapons testing fallout and industrial releases (including medical wastes). Nuclear industry sources include uranium mill tailings, enrichment and processing, spent fuel (fission products and transuranics), low-level operations, and research by-products.

This problem area is characterized by a well-developed historic (and aging) literature with a well-developed risk methodology, and extensive standards development and regulatory oversight. Environmental transport mechanisms and pathways are known; biological/ecological effects are organismally based. Current public concern is over environmental contamination and perceived human health risks, with contaminant concern over environmental movement and remediation. Ecological effects are minimal under current practice. Regulatory philosophy holds that protecting humans protects the environment, based on the general greater radiosensitivity for humans than for other biota.

The Subcommittee estimates that ecological risks of these sources are minor under current practices, with relatively low uncertainty and number of unknowns. Thus, we disagree with Unfinished Business statements of uncertainty for ionizing radiations. Non-ionizing UV-B radiations are not addressed here (see Stratospheric Ozone Depletion, Section 6.3), and non-ionizing electromagnetic radiations have minimal (and localized, if any) environmental effects.

The Subcommittee agrees that the low ecological risk ranking is appropriate.

6.3 Stratospheric Ozone Depletion

The issue of stratospheric ozone depletion (problem area 7) was reasonably represented in the issue paper in the EPA report, although a number of developments have taken place in the intervening three years. It is still true that the main cause of present and projected stratospheric ozone depletion is attributable to production and release of chlorofluorocarbons (CFCs) (EPA and UNEP, 1986; Hoffman, 1987). Worldwide emissions of CFCs remain substantial, but there has been considerable progress in establishing future limits internationally on CFC production, beginning with the Montreal Protocols of 1987 and continuing to the commitments made by Europe and the U.S. in 1989 to phase out virtually all CFC production in the next few decades (Wigley, 1988). Consequently, projections of future CFC emissions would be reduced from projections made three years ago (Lashof and Tirpak, 1989; Smith and Tirpak, 1989). On the other hand, not all nations have made these phase-out commitments, and substantial inputs to the atmosphere will continue for some time. Further, there is a significant time-lag between cessation of emissions and reductions in atmospheric, especially stratospheric, concentrations. Indeed, residence times for CFCs are typically measured in decades or longer, and stratospheric concentrations will continue to increase because of atmospheric dynamics even if all emissions were to cease immediately (Lashof and Tirpak, 1989; Smith and Tirpak, 1989).

Over the past three years, there is also an improved understanding of the atmospheric chemistry of CFC-stratospheric ozone interactions. For instance, the experience of the very large stratospheric ozone depletion event over Antarctica in 1987 and 1989 has shown how CFCs, interacting with stratospheric ice crystals and with sunlight as it first reaches the stratosphere in the austral spring, can very rapidly deplete stratospheric ozone (Stolarski, 1988; Rowland, 1988; Shea, 1989). This ozone-hole phenomenon did not appear in the earlier models of atmospheric chemistry, but has now been seen as well over the Arctic. Furthermore, estimations of columnar ozone depletion over the last 15 years or so now exceed 5% for northern mid-latitudes, somewhat larger than the original EPA issue paper suggested. Consequently, there has been an increased sense of urgency added to this issue. This urgency has been responsible for the progress noted above on regulating global emissions of CFC's.

With respect to potential effects of enhanced UV-B radiation on biological systems at the surface of Earth, there continues to be a very inadequate data base to evaluate effects. We can state with confidence that UV-B, in general, is biologically important, as it is strongly absorbed by biologically critical compounds (e.g., DNA), and, thus, like ionizing radiation, has the generic potential for deleterious effects on biota (Worrest, 1985). Experimental data on UV-B effects show sensitivity for many marine planktonic and larval species, and there is a general consensus that enhanced UV-B could lead to adverse consequences on marine and coastal ecosystems (Worrest, 1985; Hoffman, 1987). However, experimental data on UV-B effects on most terrestrial plants are lacking; for example, how enhanced UV-B would affect the trees in a tropical rain forest is essentially unknown. For crop plants, about 200 cultivars have been tested, for which about one-third are insensitive, and another third very sensitive, but experiments have not been conducted for many important crops (e.g., work has been done on only a very limited number of cultivars of rice). Thus, assessing the potential biological consequences of increased UV-B is difficult at present, although a research effort to obtain UV-B dose response data for plants of ecological or agricultural importance would reduce those uncertainties readily and with limited expense.

Secondary and indirect effects of increased UV-B are poorly known; examples of potential indirect effects include increased susceptibility to disease or pests by terrestrial plants. Similarly, little is known about interactions of enhanced UV-B with other concurrent stresses, such as water stress from climate change. Again, an experimental program could reduce these uncertainties considerably.

The EPA ecological workgroup ranked stratospheric ozone depletion as being of very high concern. We concur with this ranking because: 1) the mechanisms for adverse biological effects are common across biota; 2) the stress will be globally distributed and, therefore, something to which virtually all ecosystems and agricultural systems will be exposed; 3) the time-frames for the stress on the environment are long (decades to centuries); 4) it is not possible to mitigate against the ecological effects of increased UV-B; and 5) it may be difficult to adapt agricultural systems to enhanced UV-B at the same time adjustments are to be made for climate change stresses.

6.4 Global Climate Change

The issue of concern here relates to anthropogenic emissions to the atmosphere of gases that have radiatively important properties (i.e., they absorb light at wavelengths that control the Earth's thermal balance). Continuous rate of these emissions are expected to lead to a greenhouse response, with projected global climate change to occur over the next few decades at magnitudes previously seen only over geological time frames (Bolin et al., 1986). The EPA issue "CO_2 and global warming" (problem area 8) is more properly labeled "issues of global climate change", because CO_2 is only about half of the present contributor to equilibrium temperature changes among anthropogenic emissions, and because the stresses on the environment of ecological and agricultural significance are not limited to warming (e.g., changes in precipitation often may be more important than changes in temperature).

Anthropogenic sources of radiatively important gases include CO_2, primarily from combustion of fossil fuels, but also from deforestation and cement production; CH_4, primarily from agricultural production, especially from livestock and in rice paddies; N_2O, primarily from agricultural releases, especially from bacterial action on fertilizers; and CFCs, the same compounds of central concern to stratospheric ozone depletion (Keeling et al., 1982; Bolin et al., 1986; Bolle et al., 1986; Lashof and Tirpak, 1989; Smith and Tirpak, 1989). Insofar as CFC emissions are limited for ozone-depletion reasons, this will make a significant difference to the eventual magnitudes and rates of climate change over the next several decades (Wigley, 1988). On the other hand, even with complete elimination of CFCs, CO_2 production globally will continue to increase, with the greatest growth in emissions attributable to developing countries (Lashof and Tirpak, 1989).

Present best estimates of globally averaged temperature increases at equilibrium are between 1.5 and 4.5°C for an effectively doubled CO_2 atmosphere (i.e., with total radiatively important gas concentrations increased to the level equivalent to doubling of CO_2 if that were the only radiatively important gas) (NAS (1979, 1983, 1987); Smith and Tirpak (1989); Bolin et al. (1986); MacCracken and Luther (1985)). While these numbers are useful for comparisons to paleoecological records or to compare the relative effects of alternate strategies for controlling greenhouse effects, a globally- and annually-averaged temperature increase does not capture the important stresses from an ecological or agricultural effects perspective. Issues of spatial and temporal scale are critical, as are issues of changes in the frequency, intensity, or duration of extreme events (as opposed simply to changes in averages). That is, what will have most importance to causing biological effects will be climatic extremes, and a shifting climate, even with unchanged relative variances, will likely lead to an increase in extreme events. Moreover, whereas the physical stresses of global climate change will be distributed globally (albeit not uniformly), the biological and human effects will occur at local and regional scales and must be evaluated at that scale (Harwell et al., 1985a).

The present scientific consensus emerging is that global climate change will occur in the next few decades; there is less agreement that climate change has already occurred (data support temperature increases in the last few decades for the entire planet, but not for the United States, for example) (Hansen and Lebedeff, 1988; Hanson et al., 1989; Jones and Parker, 1990). Further, even if climate change is accepted as occurring at present, there is no consensus that such change can be causally attributable to anthropogenic emissions or other human activities (e.g., Kerr, 1989). Nevertheless, that climate change will occur is widely, although not universally supported in the scientific community. How much climate will change, in what regions, and at what rate, are issues of much less agreement, and considerable uncertainties remain in projections. How general circulation models treat cloud formation, atmospheric-ocean interactions, and biological feedbacks (e.g., changes in rates of biogenic gas production, changes in albedo, and rates of evapotranspiration), are issues in need of considerable scientific research (e.g., Robock, 1983; Dickinson, 1986; Hansen et al., 1984; Broecker, 1987).

On the biological effects side, it is clear that temperature is not the only, or often even the most important, stress associated with global climate change. Precipitation changes, in intensity, location, and timing, are much more likely to affect, for example, agricultural production than are increases in growing season temperatures for many regions of the world (Parry et al., 1988a,b). Changing water relations, and the effects of climate change on hydrologic cycles, could have a major impact on regional water balances of the continents. Other issues of ecological importance include sea-level rise, presently projected to be about 0.3 - 1.0 meter by the middle of the next century, from thermal expansion of the oceans (Smith and Tirpak, 1989; Lashof and Tirpak, 1989). Sea-level rise would have major consequences on coastal ecosystems, including wetlands, estuaries, and spawning grounds for fisheries. Other physical stresses associated with global climate change may include changes in the frequency and intensity of storms, shifts in ocean currents and upwelling areas, and shifts in the intra-tropical convergence zone and in patterns of monsoonal development, among others.

Estimating biological effects can be done by using a range of analytical methodologies to relate changes in the physical environment with crop productivity as well as ecosystem distribution. Available methods include historical analogs (e.g., Stommel and Stommel, 1979); statistical models (e.g., Uchijima, 1981); physiological experiments (e.g., Uchijima, 1982); life zone classifications (e.g., Emanuel et al., 1985); paleoecological records (e.g., Davis and Botkin, 1985); simulation models (e.g., Harwell et al., 1985b), and expert judgment. For example, physiologically based crop simulation models can be used to estimate how changes in climate will affect phenology and yield of particular crops at specific locations. Equilibrium ecological effects can be estimated from paleoecological analogs and by examining bioclimatic life zone shifts, with associated changes in the distributions of biomes. But much research on effects remains to be done, including some experimental (e.g., how crop yields or ecosystem productivity would change in combinations of altered climate and enriched CO_2 - see review in Idso, 1989), and other more theoretical research (e.g., model development and sensitivity analyses).

Effects of global climate change are only broadly estimated at present. This is an area of particular importance and relevance to EPA. Indeed, in the growing national program on global climate change, effects issues appear to be given insufficient attention, yet it is the effects on ecological, agricultural, and human systems that are of real concern and that must be understood in order for policy options to be properly evaluated. The issue of global climate change was given the highest ranking by the EPA ecological workgroup. We concur with that ranking because: 1) the potential for biological effects is so large and ubiquitous since the physical climate has such an important control on ecological systems as well as crop productivity; 2) the time-lags built into atmospheric, oceanic, and biospheric systems are so long that actions today will have consequences for decades to come; 3) it is not possible to mitigate against climate change occurring from gases that have already been emitted to the atmosphere; 4) it is possible to mitigate against the effects of climate change, especially for agricultural and societal systems, but a much better understanding of the spatial and temporal distribution of climate change and a much better understanding of the environmental and human effects of climate change are essential before proper mitigation can be designed; and 5) with appropriate attention by EPA to biological effects issues, a critically important but otherwise insufficiently addressed facet of the global change issue can be significantly advanced.

6.5 Direct and Indirect Point Source Discharges to Surface Waters

Direct and indirect point source discharges commonly refer to the discharge of pollutants to surface waters from publicly-owned waste treatment facilities (POTW) (15,000) and industrial outfalls (24,000) (EPA, 1987b). These discharges are regulated by EPA through a permit system (National Pollutant Discharge Elimination

System, NPDES) that allows release of both conventional and toxic pollutants at specified levels. Dischargers are clustered in the eastern and midwest regions, where human and industrial activities dependent on aquatic resources are most dense (EPA, 1987b). Many industrial operations contribute to the load reaching municipal waste treatment facilities, and therefore, are indirect dischargers to aquatic systems. Waste treatment facilities discharge mainly to rivers (except in coastal zones) experiencing seasonal fluctuations in flow. Low flow in receiving water (e.g., late summer; drought periods) often leads to high concentrations in water and potentially deleterious impacts on the aquatic ecosystem. Conventional pollutants of major concern are BOD (biochemical oxygen demand), suspended solids (SS), and nutrients (P in freshwaters; N in estuarine waters). The latter lead to excessive growth of undesirable algae and aquatic plants. Toxic pollutants include trace metals (e.g., Cu, Cd, Cr, Hg) and organic compounds (PCBs, phenols, etc.). Most current requirements for controlling discharges are technology-based rather than water quality-based, although there is a trend toward more water-quality-based regulations.

Although strategies to limit discharge of conventional pollutants are improving, removal of toxic chemicals requires a fully-implemented industrial pre-treatment program. Point-source discharges also include combined sewer overflows. Many of the industrialized cities of the eastern and central states are moving to separate municipal waste and urban runoff.

We recommend that a wider variety of chemicals than presently are regulated be monitored in both discharges and receiving waters. In addition, a clear understanding of the ecological impact of municipal and industrial discharges is badly needed. EPA ranked this issue in Group 3.

6.6 Non-Point Source Discharges to Surface Waters Plus In-Place Toxics in Sediments

The EPA document (EPA, 1987b) states that "the major ecological risk from non-point sources is ...agri-cultural...erosion". Non-point source pollutant inputs to surface waters, however, also include erosion from other sources (e.g., silviculture, mining), groundwater transport, atmospheric deposition, urban runoff, and resuspension/recycling of in-place pollutants. The best known of these inputs is erosion of surface soils resulting from land disturbance by agriculture, development, and natural processes (e.g., hurricanes; flooding). Groundwater contaminated by pollution activities on land may contribute to the pollutant load of nearby surface waters. In Switzerland and Germany, there are many examples of surface waters contaminating local groundwaters through bank infiltration. The problem of atmospheric deposition of toxic elements and chemicals to aquatic ecosystems has been emphasized by the role the atmospheric pathway plays in the Great Lakes. In general, the processes leading to removal of contaminants from the atmosphere and the air-water exchange of volatile species are not well understood (Eisenreich et al., 1981; Strachan and Eisenreich, 1988). The importance of atmospheric deposition to pollution inputs in other aquatic systems such as Chesapeake Bay needs to be studied.

The most severe problems associated with in-place pollutants occur in bay and harbors that have received extensive inputs of particle-reactive organic compounds and toxic metals. These pollutants continue to recycle in the ecosystem by natural (e.g., bioturbation; winds) and anthropogenic processes (e.g., dredging; ship traffic; continued inputs) for decades and longer. Examples of areas where in-place pollutants are a particular problem are New Bedford Harbor, Waukegon Harbor, Fox River/Green Bay, Toronto Harbor, Los Angeles Bight, and Long Island Sound. However, rivers, lakes, estuaries, and coastal waters where sediment deposition accumulates, and near urban/industrial centers, have bottom sediments with measurable quantities of toxic metals and organic compounds. Even at low concentrations, some chemicals may move into benthic organisms and concentrate in the food chain. Although most interest has been in protecting health of humans consuming fish from contaminated areas, more attention must be placed on the interaction of benthic organisms with in-place pollutants.

Control of non-point sources of pollutant inputs to surface waters may be difficult and expensive. In the case of atmospheric transport and deposition of pollutants, sources are often diffuse, distant, and uncontrolled or unidentified. The Subcommittee expands the scope of concern beyond the Unfinished Business document to include the above and agrees with a Group 3 or high ranking. For the special case of pollutant emission to the atmosphere, and then transport over long distances before deposition, the Subcommittee ranks this problem high on a regional scale, and medium on a global scale.

6.7 Contaminated Sludge

Sludge is one of the residuals or products from pollution control or treatment systems. Since these systems are designed to prevent hazardous substances and/or pathogenic organisms from reaching the environment, it is not surprising that sludge is usually contaminated. Sludge also can be generated by various industrial processes, but industrial sludges are more appropriately covered by other sections and are not considered here.

Based on the data available, the authors of the EPA support document concluded that, "...disposal of contaminated sludge should not be expected to result in extensive damage to natural ecosystems where reasonable anticipated control programs are properly implemented" (Appendix III, Page 59). They further concluded that damage would likely occur if control programs were not carried out. The implicit assumption is that "reasonably anticipated control programs" were designed with knowledge and understanding of all (or most) of the hazard and exposure aspects of studies. Recent data indicate that there have been important omissions, e.g., the recent attention being given to the hazards of municipal solid waste incineration ash.

The Unfinished Business document supports the premise that there are a number of unknowns and uncertainties related to the potential environmental impact of sludges. Among these is the contention that information is available for only some of the many different chemical pollutants and pathogens associated with sludge. In addition, it is stated that only limited efforts have been expended on in-field documentation of ecological impacts of sludges. The assumption that current and "reasonably anticipated control programs" will minimize environmental impacts is not supported by the document.

The massive quantities of sludge presently being generated, the wide array of sludge contaminants, and the projected increases in sludge generation, necessitate that current and anticipated sludge regulations be as effective as possible in order to minimize ecological impacts.

The Subcommittee agrees with the basic risk ranking for sludge of low to medium, depending on the area being exposed. Localized impact can be much greater (e.g., the 12 Mile Dump Site), but relative to such issues as global climate change, it does not warrant a high ranking.

6.8 Physical Alteration of Aquatic Habitats

Although current environmental laws require mitigation and enforcement to compensate for wetland destruction for some federal programs, a majority of the habitat loss in the United States results from currently unregulated activities or processes. Channelization and drainage for agricultural production, impoundments of total wetlands for private use, erosion-caused sedimentation of stream habitats, destruction of riparian communities by animal grazing, and bulkheading and filling for shoreline development are all prime examples of poorly regulated activities leading to wetland destruction.

Many of these activities are associated with agricultural practices throughout the country or with coastal developments associated with urban expansion. Activities on public lands should be required to abide by sound environmental practices, independent of which agency has the administrative responsibility.

Although the impacts of any single activity are local, the activities are common throughout the country and the impacts are cumulative. The aggregate impacts amount to an unacceptable loss of ecological resources, and the irreversible nature of the impacts on biological diversity and ecological productivity requires a major programmatic emphasis across all governmental organizations.

Several specific activities warrant special attention. Draining and filling of isolated freshwater wetlands by agriculture should demand the same regulations as those required of the Federal Department of Transportation. Public construction grants that support infrastructure development (e.g., roads, sewers, water supplies, and power networks) should not provide support in coastal areas characterized by tidal marshes and coastal estuaries. Local zoning ordinances cannot be expected to protect priority aquatic habitats once the infrastructure is constructed. Commercial fisheries operations using throw nets or trawls physically impact benthic habitats. These activities should be restricted from critical areas. Animal grazing needs to be regulated on riverine communities along rivers, streams, and pocket wetlands.

A viable aquatic habitat includes a diverse and productive terrestrial community adjacent to the land-water boundary. Sedimentation control is likewise required to protect riverine habitats. EPA should adopt and enforce a watershed management paradigm for aquatic habitat protection. This regulatory approach should be implemented by all federal organizations that have managerial responsibilities for public lands.

The Unfinished Business report ranks this irreversible trend in habitat destruction in Group 2. For the above reasons, we concur with this emphasis on aquatic habitat loss.

6.9 Active Hazardous Waste Sites

The Unfinished Business report ranks active hazardous waste sites in Category 6 (low risk). The Subcommittee challenges this conclusion based on future trends and not on current data. This category includes the operations of incinerators, land disposal facilities, recycling units, and other chemical/physical/biological treatment technologies.

The locations of these operations are usually a function of source location and can be found in a wide array of environmental settings. These facilities require the transportation, storage, transformation, and disposal of a great variety of organic and inorganic toxic substances and pathogens. These materials come from chemical industries, defense industries, municipalities, medical industries, and agribusiness.

The assumptions in the Unfinished Business Report are that active hazardous waste sites are currently regulated by RCRA/CERCLA and, therefore, are or will be well designed, constructed, and managed. Environmental releases of vapors to the atmosphere and leachates to the surface and groundwaters are expected to be low, and the effects limited to local impacts. These are the same assumptions that were made for the last generation of permitted hazardous waste sites with obvious shortcomings. These sites were permitted by State and Federal agencies with the full expectation that the technologies would be adequate to protect the environment.

Active hazardous waste sites are not environmentally benign, and there still exists a number of important scientific issues that are not well understood and documented that produce significant uncertainties about many of these technologies. The perception that leachates only migrate slowly through the saturated zone of the soil has been challenged by recent research at the Oak Ridge National Laboratory. Episodic events of heavy rains produce rapid horizontal migration of toxicants through the unsaturated zone, resulting in increased loadings to surface wetlands. Clay liners and clay caps on landfills with backup leachate collection systems are designed to prevent and remove leachates. It took two decades for the failures of our last generation of landfills to present themselves. Few, if any, of the new generation of engineered landfills have been operating long enough to document the real performance with field data. Usually the weakest link is the management after a routine pattern of operation has developed.

The controversies surrounding incinerators are far from resolved. The chemistry of combustion associated with large-scale incinerators receiving a feedstock flow of variable quality is not well known. It was only in the last decade that we associated the formation of chlorinated dioxins with thermal treatment. Many of the residuals from incinerators are discharged directly into the atmosphere, which increases the spatial scale of dispersion.

The EPA Unfinished Business Report characterizes the impacts as localized and potentially reversible over a 10-year period. This conclusion is not supportable. The wide distribution of sites produce a cumulative pattern whose impacts are not local. The reversibility of impacts from resilient toxic compounds in soils and groundwater requires far more than 10 years.

We recommend that this category be given the same rank (i.e. Group 5) as the other toxic waste stream categories instead of the Group 6 ranking given to it in Unfinished Business.

6.10 Inactive Hazardous Waste Sites

Past disposal practices for hazardous waste often met legal requirements at the time, but the resulting contaminated soils and groundwater and air emissions have become a major concern for the present and future. The primary focus of this concern is on the substances released from these sites that could impact humans via surface water, groundwater, or air. Less attention has been paid to the ecological impacts of such releases.

At the time Unfinished Business was written (EPA, 1987a,b,c), there were 888 sites on the National Priority List (NPL). Groundwater contamination was found at approximately 75% of those sites, surface water contamination at 45%. A survey of 540 sites listed the 15 most frequently observed chemicals as TCE, lead, toluene, chromium and compounds, benzene, chloroform, PCBs, tetrachlorethane, trichloroethane, zinc and compounds, arsenic, cadmium, phenol, ethylbenzene, and xylene (EPA, 1987a). There are now 1,175 NPL sites, and EPA estimates that there will be more than 2,100 by the year 2000 (Lucero and Moertl, 1989).

Hazardous wastes account for approximately 20% of all industrial wastes and are produced by virtually every type of manufacturer (Paisecki and Davis, 1987). Further, chemicals in the waste do not remain fixed where they are deposited. Some wastes have appreciable vapor pressure or are gaseous at ambient temperatures (e.g., vinyl chloride trapped in PVC processes) and will diffuse through fill, appearing in ambient air at the site. Chemicals can often leach into underlying aquifers and be transported via groundwater flow. Contaminated groundwater may eventually feed surface waters, contaminating streams and lakes or, possibly, nearshore marine habitats (Peirce and Vesilind, 1981).

Nearly all chemicals found at inactive waste sites are toxic and known to have chronic or acute effects on organisms. However, there are limited data on the concentration of the substances and the exposures that animals and plants experience. Although there is little information on ecological effects at Superfund sites, a survey estimated that 6% of the NPL sites are likely to have significant damage to natural resources such that natural resource damage awards are likely to be sought under CERCLA (EPA, 1987a,b).

There could be significant ecological impacts if toxic and persistent chemicals (e.g., PCBs) contaminate sediments in aquatic habitats (e.g., harbors, wetlands). This scenario sets the stage for long-term exposure of organisms, particularly the benthos.

Hazardous waste generators are facing a shortage of existing landfill capacity, which has a projected lifespan of 10 to 15 years unless something is done to decrease the amount of waste (Nelson-Horchler, 1988).

EPA placed this category in Group 5. The Subcommittee currently ranks the ecological risk from inactive hazardous waste sites as medium (M) because ecological impacts tend to be localized in the immediate vicinity of the site. However, the number of known sites and their potential to release toxic and persistent compounds into the environment are of sufficient concern to warrant close and continuing attention to this problem from an ecological as well as human health perspective.

6.11 Municipal and Industrial Non-Hazardous Waste Sites

Some non-hazardous waste landfills contain only municipal or industrial wastes, and some contain wastes contributed by both groups, in varying amounts. The Subcommittee believes that, from an ecological standpoint, these waste sites should be considered together. Non-hazardous waste landfills will eventually generate leachate and gaseous releases (Charnley et al., 1988; Webster, 1988). Releases from these landfills may be to the atmosphere, soils, groundwater, and surface water. Potential effects are to biota as well as human health.

Inputs to municipal waste sites include paper, yard wastes, food, plastics, metals, glass, textiles, wood, and a miscellaneous category that can include chlorinated organics (e.g., from cleaning fluids) and aromatics (e.g., from paints and household products). (Webster, 1988; Franklin Associates, 1988). Releases from these landfills may vary, but Wood and Porter (1986) identified 77 chemicals known to be released from municipal waste landfills, including methane, benzene, toluene, vinyl chloride, trichloroethylene, and methylethylketone.

Industrial non-hazardous waste sites usually contain substances specific to a particular operation and may be located on an industrial facility site or at a site that combines wastes from a number of different industrial contributors. Examples include wastes from building demolition, phosphate fertilizer manufacturing, or oil-drilling operations. Landfarming has been extensively used for some of these wastes (Huddleston et al., 1982).

It is not possible to predict how long it will take for a particular landfill to stabilize to the point where it will no longer produce and release products. However, Charnley et al. (1988) cite a report by Pohland et al. (1983) which describes 5 stages in the life of a landfill. Each stage yields characteristic compounds that are released to the air or to leachate.

Stage 1. Initial Adjustment - This stage occurs after the refuse is placed in the landfill until it has absorbed moisture. Little, if any leachate is formed during this stage. Stegen et al. (1987) estimated that this stage takes 6-18 months.

Stage 2. Transition - During this stage the refuse has absorbed moisture and begins to form leachate. Microbial degradation changes from aerobic to anaerobic.

Stage 3. Acid Formation - Anaerobic degradation continues and volatile organic acids reach their highest concentration. The pH declines rapidly.

Stage 4. Methane Fermentation - The intermediate products formed in stage 3 are converted to methane and CO_2. The pH of the refuse is buffered by a bicarbonate system. The amount of leachate decreases, but the amount of gas produced increases.

Stage 5. Final Maturation - Microbial action is limited due to decreased availability of nutrients. Gas production ceases and oxygen and oxidized species slowly reappear. Compounds resistant to microbial digestion are converted to humic-like substances capable of complexing with and mobilizing heavy metals. When the rate of change within the waste becomes negligible, the landfill is considered stabilized.

Releases from landfills that contain only municipal wastes and those that contain both municipal and industrial non-hazardous waste are indistinguishable, unless the site is dominated by a particular industrial waste. For most sites, the quantities of lignin-containing wastes, chlorinated hydrocarbons and aromatics from municipal wastes are so large that chemicals derived from the industrial wastes cannot be detected against this background (Webster, 1988).

The Subcommittee agrees with ranking the ecological risks from non-hazardous waste sites as Medium (M) (or Group 5) on the basis that the impacts are largely local. Releases are generally of low concentration. The long-term nature of the releases and the number of and distribution of sites, however, warrant continuing attention to this issue.

6.12 Alteration and Disturbance of Terrestrial Habitats

This topic was not addressed or ranked in the EPA Unfinished Business report. The Subcommittee feels that it is an important, ubiquitous ecological problem contributing toward loss of biological diversity and therefore should be considered.

As human populations and their support systems expand, natural habitats and the populations they support are disturbed, altered, or destroyed. There is a consensus among ecologists that species extinctions are now occurring at unprecedented rates (Wilson, 1988; Wright, 1990). The major cause of species loss is destruction of natural habitats. The most significant and publicized losses currently are the results of conversion of tropical forests to agriculture in Latin America and Southeast Asia. However, natural habitat losses are occurring everywhere, even in industrialized countries with strict environmental regulation. For example, oak woodlands and chaparral are rapidly being converted to housing tracts and avocado orchards in southern California mountains. Most native prairies and grasslands in the United States have already been converted to agriculture.

Habitats can be altered, converted, or disturbed with varying ecological impacts. Conversion of a habitat results in irreversible loss; e.g., a forest is converted to a housing tract, and survival of native plant and animal populations is no longer possible. Partial alteration of a habitat (e.g., road construction) can result in shifts in diversity and abundance of natural populations, but may allow survival of the ecosystems. Habitat disturbance may be caused by human activities near natural populations (e.g., aircraft overflights) and result in abandonment or decreased use of the habitat. For example, allowing public access to a previously isolated beach causes harbor seals using that beach as a rest area to abandon it (Bartholomew, 1967; Woodhouse, 1975).

Although the impacts of any single activity are local, the cumulative result is major, and for the most part, results in irreversible loss of natural ecosystems, including species extinctions.

Every effort should be made to preserve native ecosystems in parks, reserves, and sanctuaries, but this action alone will not significantly reduce the rate of losses. An equal effort is needed to minimize the impacts of development so that, to the extent possible and practical, natural populations can survive. For example, leaving corridors of natural habitat through developed areas allows more native populations to survive (Millar and Ford, 1988). More attention should also be paid to restoration and enhancement of natural habitats (Jordan et al., 1988), including research programs to build the science base upon which these activities rely.

Some types of development are more compatible with natural systems than others. Such projects maintain a large portion of the property in open space, permitting the survival of natural populations. Examples of these are military bases, oil fields, and low-density housing. These projects should be planned with the goal of maximizing the survival of natural populations while accomplishing the goals of the project.

Finally, sound environmental planning and management to minimize the ecological impacts of development should be a part of every approved project. More research is needed to develop cost-effective environmental planning and management methods. Lengthy, detailed ecological studies are not a realistic expectation for most development projects, yet accurate, reliable data are needed for use in planning.

The Subcommittee sees habitat alteration and loss of biological diversity as a local, regional, and global problem of increasing importance with high cumulative impacts and, therefore, high ecological risks.

6.13 Accidental Releases of Toxics

Over 2,000 accidental releases of toxicants occur annually involving some 40 million pounds of the total. Only 2.4% of the events release 90% of the total amounts of toxicants. Most of these come from fixed facilities and occur on land. Most states enforce emergency containment and cleanup procedures at large facilities.

The EPA Unfinished Business Report downgraded the importance of persistent toxicants (PCBs, Kepone, dioxins, etc.) since they do not constitute a large percentage of the total spills. A majority of the materials accidentally released are nonpersistent organics like TCE and DCE. Given the above, the low risk ranking is appropriate.

6.14 Oil Spills

On average about 11 million gallons of oil are spilled each year; 60% of this amount is spilled into marine environments and 40% in inland environments. Approximately 40% of all oil spilled is crude oil, 30% diesel and other fuel oils, and the remaining 30% other products (EPA, 1987).

Most experimental and monitoring work has been done on crude oil spills in the marine environment. A large body of literature has been developed since the Torrey Canyon spill in 1967 and the Santa Barbara spill in 1969 (e.g., API, EPA, USCG Oil Spill Conference Proceedings 1969-1989). Large oil spills, though infrequent, can have significant ecological impacts. Spills of crude oil in the marine environment are primarily surface events rather than water-column events. The most severe (i.e., population-level) impacts are on organisms that interact with the water surface and oiled shorelines. Water column and benthic populations are affected far less, usually not at the population level. Impacts of most oil spills, even large ones are in the "years" category of duration (NRC, 1985). This is likely to be the case for most populations affected by the large 1989 Exxon Valdez spill in Prince William Sound, Alaska, as well (Baker et al., 1990). The exceptions to this are spills that enter low-energy habitats where oil penetrates the sediments and may remain for long periods. For example, oil spills kill adult mangrove trees. It may take 20 years to replace such trees.

Spill-response techniques can greatly influence the ecological impacts of the spill. In spill situations there is often a conflict between the goal of removing visible oil from the environment and that of minimizing the ecological impacts of the spill. There are many examples where harsh and damaging "cleanup" methods have actually increased the overall impacts of the spill and prolonged recovery (e.g., using heavy equipment in marshes and steam cleaning to remove oil from rocks). We recommend that the overall goal of spill responses should be to minimize the ecological impacts of spills and that response methods be chosen to accomplish this goal and, preferably, planned in advance. The importance of site-specific contingency planning and of streamlined decision-making during a spill event cannot be overemphasized (Lindstedt-Siva, 1984).

More research is needed on the fate, effects, and response methods for spills of crude oil and products into inland waterways. For some of these products there is significant potential for water-column or benthic, as well as surface, effects. In addition, some of the response methods appropriate for spills in marine environments are not appropriate for inland waterways.

The Subcommittee agrees with the overall ranking of Group 5 or Medium (M) for the impacts of accidental oil spills. The rationale is that spilled oil degrades, loses toxicity, and generally does not persist in a biologically active state in the environment for many years as, for example, chlorinated hydrocarbons do. The most serious, longer-term impacts from accidental oil spills have been from spills of refined products (more toxic than crude oils) into low-energy, confined bodies of water where the oil has become incorporated into sediments.

6.15 Underground Storage Tanks

It has been estimated that from 10% to 25% of the underground storage tanks (USTs) in use currently are leaking. This may engender ecological risks not apparent to similar lack of containment for the same materials stored above ground. At first glance, the major potential for UST contamination of the environment would be that associated with contaminated groundwater, particularly in those rural areas where potable water is derived from shallow wells. However, over a long time period such contamination of groundwater with petroleum products may be significant to some surface waters derived from contaminated aquifers where the ecological effects may be more apparent. In cases of known leaking USTs, removal is required, with decontamination of the affected environs at considerable expense to the owner of the site. In cases where a family business is the responsible party, the costs of such remediation may result in cessation of business and possible inadequate financial resources to implement remediation, leaving the problem unsolved. This problem, then, has serious economic consequences as well as the potential for environmental perturbations. The problem of leaking USTs is widespread and perhaps cumulative over the years, reflecting lack of comprehension of the problem and its potential for harm.

The prevalence of the problem and the impact on small business and landowners and the potential for cumulative effects suggest that several research areas need to be developed to ameliorate this widespread problem.

Additional research should be implemented towards the development of devices and procedures for early detection of leaking USTs, which will enable periodic inspection and certification of such tanks. Such detection ideally should be low-cost and involve minimal perturbation of the environs of the tank and the business activity at the site. Reliable devices of high sensitivity that can be operated by individuals with minimal technical skills should be developed as an analog of more sophisticated technology currently available.

Research should be implemented towards the remediation of contaminated soils near a leaking UST. Such research might be focused on in-situ remediation, remediation in close proximity to the contamination site, or utilizing slurry reactors in a closed system. For these alternatives, developments in biotechnology currently available for bioremediation should be considered and evaluated to minimize the cost of remediation if prescribed.

In general, the ecological risk from leaking USTs is low, but the risk to humans may be high in cases where potable water supplies are derived from shallow aquifers down gradient from the storage tank. We agree with the ranking of Group 6.

6.16 Groundwater Contamination

Groundwater contamination is perceived by the public to be a major class of environmental insults. The EPA Unfinished Business report includes statements like "200 contaminants have been identified" and "millions of occurrences are found nationwide." The medium rank assigned in the EPA report was based on the assumption that ecological impacts can only occur when groundwater discharges to the surface. The filtering properties of soil and the dilution by surface waters will reduce the risk by reducing exposure concentrations.

The filtering properties of soil constitute a short-term buffer. Eutrophication of freshwater lakes from old septic fields, selenium toxicity of emerging groundwaters resulting from increased irrigation, and nitrate inputs into Chesapeake Bay from intensive agriculture on the Eastern Shore are all examples of overloaded filtering capacity.

The "dilution is the solution to the pollution" paradigm only works for substances that do not partition to media other than water and do not bioaccumulate. Nuisance growth of aquatic macrophytes due to excessive nutrients and the food-chain biomagnification of persistent pesticides are examples of alternative fate-and- transport dynamics.

Groundwater contamination sources are very numerous and ubiquitous (e.g., septic fields, injection wells, land applications, material stockpiles, pipelines, and non-point sources). Groundwater is generally slow moving and very conservative in transformation functions. There are very little data on groundwater as a source of ecological exposure. Most of the exposure will occur in the future.

The Subcommittee ranked the ecological risks from groundwater contamination to be relatively low. The major impact would be felt by human consumers rather than ecological systems.

6.17 Pesticides

One of the side effects of pesticide use is environmental contamination. Pesticides and herbicides are the only substances that are intentionally applied to the environment because of their biological toxicity. Society in general, and EPA in particular, are aware of this, and pesticide regulation through registration and reregistration, enforcement, and monitoring is currently of high priority.

The cost of pesticide development has increased dramatically, and the number of compounds restricted or banned has increased steadily in the last 20 years. The use of pesticides in the United States increased during the 1970's, leveling off at a little over one billion pounds of active ingredient since the mid- to late-1970s. In fact, the amount of active ingredient used in the United States in 1988 was 1.13 billion pounds, about the same as in 1978 (1.11 billion pounds). Clearly the degree of environmental contamination and risk to the environment depend on such factors such as toxicity of the pesticide, application methods, and its persistence. We are concerned about this contamination and encourage EPA to continue to develop environmental monitoring methods.

We are also concerned by the efficiency of controls given current application practices, in particular, the overuse of pesticides and improper use by unskilled or untrained consumers and farm workers. The different application approaches used which depend on the type of pest, its location, and the specific type of pesticide to be used can result in much of a pesticide sprayed on the environment never reaching or impacting its target.

Research on non-pesticide control needs to be a priority for EPA. Pesticides, by their very nature, are toxic to the environment, and pollution prevention or non-use of pesticides should be a long-term goal. We believe EPA should consider taking a stronger role in non-chemical control of pests. Both research and dissemination of information are needed.

6.18 New Toxic Chemicals (Non-Pesticides)

Determining the environmental risk posed by a chemical(s) that has yet to be conceived or produced is impossible. The Toxic Substance Control Act (TSCA) directs EPA to evaluate the hazards and exposures associated with new industrial chemicals and determine whether the potential risks are acceptable.

The EPA Unfinished Business background and reference documents indicate that approximately one thousand new chemicals have been developed each year over the past decade. It is further implied that half are now in production. Laboratory toxicity assessments have been conducted on some of the new chemicals reviewed by EPA's Office of Toxic Substances since 1979. Many do not have adequate ecotoxicity data for a "reasoned ecological risk assessment", the criterion specified in TSCA.

To compensate, in part, for the lack of time and resources to conduct laboratory toxicity assessments, models have been developed to estimate a variety of parameters, including bioconcentration, toxicity, and persistence. Quantitative structure activity relationship (QSAR) models are examples. It should be noted that all models have limitations, and that models are not available to estimate all parameters and responses for all chemicals.

As technologies advance and human population increases, it is logical to assume that new chemicals will continue to be developed and produced. If past practices continue, too many of these chemicals will reach the marketplace with minimal or no toxicity assessment. The Subcommittee recommends that the Agency carefully evaluate its allocation of resources relative to toxicity evaluations of new chemicals. Although the Agency did not rank this problem area, the Subcommittee believes that it should rank as a medium ecological risk.

6.19 Biotechnology

The subject of biotechnology includes a wide range of disciplines, subject materials, and intended usage. For example, developments in this field range from genetically engineered microorganisms for use as microbial pesticides to plant life altered to include heterogenetic material from a wide range of life forms. Some of the concern associated with the utilization of biotechnology reflects the manner in which biotechnology products are derived; many of the developments suggested for biotechnology utilize recombinant DNA technology. Other concerns focus on the products of biotechnology and possible perturbations of the environment that may result. The distinction between methods used and the resulting products has been clearly delineated recently by the Ecological Society of America (ESA, 1989). The substance of this publication is summarized as follows: "We believe that these developments should occur with the context of a scientifically-based regulatory policy that encourages innovation without compromising sound environmental management."

Recombinant DNA technology allows the potential for complete description of altered homogenetic or heterogenetic hereditary material that might be included in the deliberate construction of biological materials with altered properties. Therefore, risk can be minimized, if not excluded, from the perspective of the genetic material involved. The primary basis for concern, then, is the behavior of the altered microorganism, plant, or animal species into which this genetic material has been added. Such altered species may have the potential for developing ascendant populations that may alter delicate ecological balances indigenous to a given environment. Such perturbations have the potential for overgrowth of new species to the detriment of the normal flora and fauna. Concerns for this possible result, then, must be ameliorated by the development of acceptable criteria to exclude such outcomes prior to the dissemination of these biotechnology products.

Bio-pesticides are agents that have been developed to eliminate or diminish pests present in the environment. They are usually defined in terms of their targets and include microbial, insect, plant, and animal targets. Their efficacy is judged by their ability to inhibit undesirable life forms and, therefore, are generally pathogenic for the target organism. Two outcomes can be envisaged from the release of such biotechnology products: a) expansion of the host range (target species) to include organisms beneficial to biological communities through mutations and recombinations subsequent to release; and b) the ascendancy of suppressed populations subsequent to the elimination of a pest agent that normally limits such overgrowth. Therefore, two major concerns are associated with these agents. The genetic stability of the pesticide organism should be ascertained, and the consequence of the removal of the pest from a biological community should be evaluated. These concerns may best be addressed on a case-by-case basis, reflecting the judgment of experts familiar with the particulars of a planned usage.

Many developments in biotechnology center on the production of plant life with altered characteristics. Here, as above, there is a concern for the possibility that such plants might become dominant to other beneficial life forms in a biological community and, thus, have long-term detrimental consequences. However, such concerns are also inherent to strain improvements accomplished through traditional plant breeding technology. In the case of biotechnology products and the recombinant DNA technology used for their development, however, the biotechnology-derived products are likely to be more concisely defined than the products of plant breeding. Therefore, concerns for biotechnology products should be congruent with similar concerns associated with the release of more conventional products.

One of the major ecological concerns prevalent today is the accumulation, concentration, and leaching of xenobiotic compounds into potable water supplies or their increased concentrations in the atmosphere. These problems, to a large extent, are the consequence of an industrial society and previous lack of concern for environmental perturbations by its waste products. The use of genetically engineered microorganisms to degrade xenobiotic compounds is envisaged as a logical extension of natural processes. The beneficiation of such natural processes through the use of recombinant DNA technology to produce microorganisms with enhanced degradative characteristics is the primary thrust of these developments. The usual object of such developments is the enhancement of the rate at which natural processes occur and, in some cases, an increase in the range of substrates that may be degraded. For the safe application of such microorganisms, then, a primary requisite is that these microorganisms not be pathogenic to humans and other life forms. Of equal concern is the manner in which commercial quantities of such microorganisms may be produced. Commonly, microorganisms for commercial applications are grown in nutrient solutions that allow attainment of high population levels in a short period of time. There is, therefore, the opportunity for growth of pathogenic microorganisms concurrently with the commercial species, and such outcomes must be precluded by the application of product standards. This concern, however, is focused on manufacturing technology and not the biotechnology product per se.

Pivotal issues concerning biotechnology products do not include the methods by that such products are derived per se. They do include the source of genetic material, the changes that have been made to such genetic material, properties of the host organism before and after alteration, the impact of release or escape of genetically altered organisms on indigenous organisms, and their dissemination to other ecosystems. To encourage innovation and promote economic benefits to society, appropriate policies need to be developed to regulate the content and usage of biotechnology products. In some cases, this may require the development of new regulatory purviews since these products lack precedent and, therefore, are inappropriate for some existing regulatory policies.

Regulatory agencies in place should take a proactive role toward facilitating biotechnology developments by working in concert with the developers of this technology and the end-users. A case-by-case policy seems appropriate currently until experience with these products is acquired.

The potential risk for biotechnology relates directly to the product. Since products with disparate properties and intended usage are being developed, it does not seem prudent to generalize concerning inherent risk. However, no high-risk products should be considered without exhaustive review. For example, special consideration should be given to one possible product of biotechnology, the genetic alteration of pathogenic species. With microbial species, it has been suggested that genetic alterations resulting in the loss of virulence, but maintenance of colonizing activity by pathogens, might protect some plant species from infection by pathogenic bacteria. However, it is not possible to generalize in this regard, especially if all the traits contributing to virulence are poorly understood. One may envisage a genetic event occurring subsequent to release of such bacteria that might introduce new, and possibly more virulent traits, into an altered microorganism that has retained its colonizing activity toward a target plant(s). Products beyond the foregoing relationships, however, are likely to rank low to moderate risk depending upon the information base relevant to the intended usage. Biological entities, whose genetic potential and behavior are well understood, are of less concern than those known to have been developed from organisms clearly known to be associated with undesirable biological activities.

6.20 Plastic in the Marine Environment

It is common to see plastic litter along roads, and on the beaches and shorelines of our coastal environments. These materials can exhibit an environmental impact in one of three ways: aesthetic pollution; toxicity via ingestion; and mortalities from entrapment and entanglement. The magnitude of the aesthetic problem is relatively easily quantifiable. The number of mortalities from ingestion, entrapment, or entanglement is much more difficult to estimate accurately. The EPA Unfinished Business background documents do a good job of relating the length of nets, number of floats, length of ropes, number of traps, etc. in present use and the quantities lost from use and, thus, available to impact marine and estuarine organisms.

Impacts can be severe for organisms that are particularly prone to ingest plastics. Sea turtles are an important example. Individuals of these endangered species have been shown to eat plastics, and deaths have been attributed to such ingestions. Sea birds are also vulnerable.

Since accurate estimates of the magnitudes of biological impacts from plastics in the marine environment are not available, it is difficult to rank the problem. However, since endangered species are known to be impacted and the effects on fisheries have the potential to be high, the Subcommittee concluded that the area should be ranked as medium.

6.21 Biological Depletion and Extinctions

This topic was not a problem area specifically addressed or ranked in the EPA Unfinished Business report on ecological risk reduction. The Subcommittee feels that it is an important ecological problem area and that it should be considered.

There is a consensus among ecologists that species extinctions are occurring at unprecedented rates (Wilson, 1988; Wright, 1990). Many species are lost before they can be described or characterized. Others are known to be threatened or endangered, and special efforts are made to protect them. As human populations expand, there is increasing pressure on natural resources, including species harvested for food and other uses.

The major cause of species extinctions and decreases in natural populations is loss or disturbance of natural habitats. Over-harvesting is an additional cause of population reduction of commercial and sport species. When a species is lost completely, through extinction, that genetic material, adapted to its environment, is irreversibly lost. Similarly, when species become threatened or endangered or natural populations are greatly depleted, the gene pool is greatly reduced, possibly limiting the ability of that species to adapt to environmental changes. In the view of the Subcommittee, this problem area ranks as a high ecological risk.

6.22 Introduction of Biologic Species

Ecological communities are collections of biotic species that have co-evolved clusters of interspecific interactions that impact on increased probability of surviving for the participating species. These interactions involve ecological processes such as predation, competition, mutualism, symbiosis, and obligatory physical associations. Many of these evolutionary associations are so tightly coupled that small clusters of species have their fates inseparably bound together.

Introductions by natural and anthropogenicly mediated events have been analyzed by ecologists over the years, as these constitute natural experiments with which to test hypotheses involving community ecology. Generally, the frequency of successful colonizations of exotic species is low when the recipient community is not stressed. Propagules and transient individuals are constantly testing the system to look for new opportunities to expand their species domain. The resistance to intruders comes from healthy endemic populations with the competitive advantages of community co-evolution.

Even so, one of the most important demonstrable agents of ecological change is the anthropogenic introduction of biologic species into areas where they did not evolve. Intentional introductions of sport fishes, game birds, horticultural varieties of ornamental plants, and biologic agents chosen to control plant and animal pests provide thousands of case examples. In addition, a large number of accidental introductions have taken place resulting from the worldwide network of material transport in agriculture and forestry. Many of our most important pest management problems involve accidental exotic introductions.

Introductions of exotic species have provided demonstrable examples of total ecological disruption, such as the sea lamprey - alewife destruction of fish communities in the Great Lakes. They also provide examples of economic improvements with little evidence of serious ecological impacts, such as the plantings of brown trout in rivers and lakes throughout the United States. The wide array of ecological responses to the introductions of exotic species requires that each event be given careful evaluation prior to implementation. Since introductions, if successful, are usually irreversible, proactive evaluations should be mandatory.

7.0 RECOMMENDATIONS AND CONCLUSIONS

1. **Formalize an extramural and continuous process for ecological risk prioritization; this process should not be categorized by Agency programmatic structure but rather by anthropogenic stresses on the environment.**

The 1987 "Unfinished Business" report represented a pioneering effort in assessing the relative risks of environmental stressors and their prioritization for Agency attention. However, the scientific process of relative risk ranking was influenced by the programmatic structure of the Agency which influenced the organizational approach to the study. Yet the study has already been invaluable in affecting Agency operations. We recommend that the process of risk assessment be continued as a formal working tool of the Agency and that this process also include external peers -- for breadth of perspective as well as scientific credibility. It is necessary that this process continuously reappraise this nation's environmental issues and ecological risks to focus and direct Agency activities.

2. **Invest in development of formal methodologies for ecological risk assessment.**

Although the ecological and welfare risk ranking procedures used in our deliberations were a useful tool, these ad hoc procedures represent only a beginning in quantifying and formalizing risk prioritization. The process remains largely nonquantitative. There is need to improve upon existing risk ranking techniques and to evaluate methodologies for comparative risk analysis. Programmatic resources should be invested, in both in-house and extramural research and development, to improve ecological and environmental risk evaluation and prioritization methodologies. In addition, the overall concept of risk minimization (implying both controls and corrective actions) needs to be expanded to include proactive and anticipatory alternatives, such as prediction and early detection of impacts, improved design of environmental management systems, and utilization of recovery processes and self-sustainability of natural systems rather than human intervention and control.

3. **Develop the data bases needed for improving future ecological risk assessments.**

Ecological risk assessment is handicapped by the availability of organized sets of comparable quantitative data to support the risk evaluation process. The science itself lacks neither concepts or data, but is deficient in systematic synthesis of information into useful formats. All information is not necessarily useful. The risk evaluation methodologies and state-of-the-art techniques must define the data needs and data analyses. Data bases supporting ecological risk assessments must be institutionalized and maintained by the Agency. However, many useful surveys assessing ecological health are maintained by other Federal organizations. These must be accessed and used in the final processes of relative risk evaluation and risk prioritization, providing proper balance for risk reduction actions.

4. **Develop an appropriate paradigm for integrating ecological and economic perspectives and considerations.**

Any risk assessment must be based upon a comparison of benefits and costs resulting from hazard reduction. Not all environmental attributes and ecological values can be expressed in economic terms. It will be necessary to develop an entirely new paradigm for integrating ecological and economic considerations for risk assessment. Understanding sustainable development limits for ecological systems will be essential. Not until ecological and economic values of environmental systems can be unified will it be possible to obtain unbiased assessments of ecological worth, accurately to prioritize stressors and systems at risk, and to begin cost-effective strategies for risk reduction.

5. **Expand EPA's perspective on ecological values and welfare risk to include ecological attributes as well as economic factors.**

In developing an integrated ecological/economic paradigm for environmental risk assessments, it will be extremely important to address those many ecological attributes for which an economic metric presently does not exist. The costs of remediation greatly exceed expenditures to ensure early prevention of ecological damage. To address the cost/benefit of environmental actions, entirely new concepts of ecological attributes as finite resources and compounding rather than discounting when choosing alternatives to environmental protection will be necessary.

6. Incorporate the results from this risk ranking process, including the 1990 risk reduction study, in development of future Agency policy and allocation of financial resources.

The 1987 "Unfinished Business" report and this 1990 risk reduction exercise by the RRRSC have demonstrated the need for new directions in ecological research and applications. Using risk assessment techniques, these reports provide opportunity for renewed focus for reducing the risk to ecological systems based upon scientific information and expert judgment. The opportunity now exists to direct the Agency's efforts to those most critical environmental problems where the greatest risk reduction can be obtained. We urge the Agency now to incorporate the recommendations from these studies into its future policy and administrative operations.

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