ANALYSIS OF THE POTENTIAL BENEFITS RELATED TO IMPLEMENTATION OF THE CALIFORNIA TOXICS RULE

U.S. Environmental Protection Agency
Office of Policy, Planning and Evaluation
Office of Sustainable Ecosystems and Communities
401 M. Street SW
Washington, D.C. 20460

and

U.S. Environmental Protection Agency
Region IX
75 Hawthorne Street
San Francisco, CA 94105

June 1997

ACKNOWLEDGMENTS

This report was prepared under the direction of Christine Ruf, U.S. EPA, Office of Policy, Planning and Evaluation, Office of Sustainable Ecosystems and Communities, Washington, D.C., and Diane Frankel, U.S. EPA, Region IX. Industrial Economics, Incorporated performed much of the analysis and technical evaluation presented in this document. Many thanks go to the insights and encouragement offered by EPA staff during all phases of the report. In particular we wish to thank Brad Crowder for contributing his ornithological wisdom, Gary Wolinsky and Molly Whitworth for their advice on endangered species, Phil Woods for knowing (and sharing) everything there is to know about water quality criteria and standards, Keith Sappington for providing quantitative ecological analyses, Erik Beck and Gary Sheth for their contributions to Chapter 7, Matthew Mitchell for specific comment and review of previous drafts, Cheryl Henley for preparing many of the maps presented here, and Lisa A. Harris for her work on Chapter 6. Finally we would like specifically to thank the following staff at Industrial Economics for their assistance, technical support, and analysis provided during the entire project: Bob Black, Mark Curry, Brian Morrison, Matt Schwartz, Eric Ruder, and Andy Schwarz.

TABLE OF CONTENTS

EXECUTIVE SUMMARY ..... **CHAPTER 1**

Introduction 1-1
Methodologies 1-2
Results 1-9

CHARACTERIZATION OF BASELINE WATER QUALITY ..... **CHAPTER 2**

Introduction 2-1
Data and Methodology 2-5
Statewide Assessment of Toxic Water Pollution 2-9
Regional Assessment of Toxics Impairment 2-15
Conclusions 2-20
References 2-22

ANGLER HEALTH RISK ASSESSMENT ..... **CHAPTER 3**

Introduction 3-1
Methodology For Estimating Recreational Angler Risk 3-14
Freshwater Anglers 3-19
San Francisco Bay Anglers 3-30
Uncertainties 3-42
Environmental Justice 3-45
Potential Health Benefits to Recreational Anglers Associated With
Implementation of the California Toxics Rule 3-48
Conclusions: Baseline Risks and Post-CTR Benefits to Recreational Anglers 3-55
References 3-62

ECONOMIC BENEFITS ..... **CHAPTER 4**

Introduction 4-1
Methodology 4-3
Recreational Fishing Benefits Associated With
Meeting Water Quality Criteria 4-8
Non-Use Values 4-21
Human Health Benefits 4-24
Other Benefits Not Quantified 4-25
References 4-30

TABLE OF CONTENTS
(continued)

ECOLOGICAL BENEFITS ..... CHAPTER 5

Introduction 5-1
Methodology 5-8
Ecological Effects of Toxic Pollutants and Affected Resources 5-11
Toxic Pollutants and Threatened and Endangered Species 5-42
Illustrative Ecological Risk Analysis:
The Species Sensitivity Distribution Approach 5-52
Population, Community, and Ecosystem Impacts 5-53
Toxic Reductions and Potential Ecological Benefits of the California Toxics Rule .. 5-66
Limitations 5-68
References 5-70

CASE STUDIES OF ECOLOGICAL BENEFITS ..... CHAPTER 6

Introduction 6-1
San Francisco Bay 6-1
Salton Sea 6-35
References 6-44

APPORTIONING BENEFITS TO POINT SOURCES ..... CHAPTER 7

Introduction 7-1
Determination of Point Source Contributions to Toxics Loadings 7-3
Apportionment of Economic Benefits 7-19
Apportionment of Recreational Angler Health Benefits 7-24
Apportionment of Ecological Benefits 7-33
Uncertainties and Limitations 7-37
References 7-42

APPENDICES:

A: 1994 Assessment of California Water Quality, by Region, for Toxics
B: California Fish Tissue Contaminant Data Bases
C: Fish Consumption Rates
D: Supplemental Information for the Angler Risk Assessment
E: Ecology and Ecological Effects
F: Loadings Data Used in Apportionment Analysis
G: Comparison of Possible Point Source Industrial PCB Discharges in California and the Great Lakes Region by SIC Code

EXECUTIVE SUMMARY CHAPTER 1

INTRODUCTION

California is one of the most biologically diverse areas in the world. Within its 160,000 square miles of land, and hundreds of thousands of acres and miles of water resources, California harbors more unique plants and animals than any other state in the nation. The diversity of climates, landscapes, and habitats, and all the barriers to migrations such as mountains and deserts, have led over thousands of years to the evolution of a large number of unique species and varieties of plants and animals, many of which are found only in California. Many of these species exist in or are dependant upon aquatic resources during all or a part of their lives, and consequently may be adversely affected by toxic discharges to surface waters.

Clean Water Act (CWA) Section 303 requires states to adopt water quality criteria for certain toxic pollutants, and authorizes EPA to promulgate such criteria for states that fail to meet the requirements of the Act. A recent court decision has invalidated the Section 303 toxic pollutant criteria adopted by the State of California. As a result, EPA is drafting a proposed federal rule to define allowable levels of toxic pollutants for inland waters and enclosed bays and estuaries within California. The criteria EPA intends to promulgate include those for which guidance values under CWA Section 304(a) have been issued and which were not already promulgated for California in the National Toxics Rule (40 CFR Part 131 et seq.). The criteria are included as Attachment 1 to this chapter.

The toxic pollutant criteria proposed for California inland freshwater bodies and enclosed bays and estuaries are designed to protect both human health and aquatic/wildlife species, and are expected to yield significant ecological and human health benefits when implemented by the State. In addition, reducing toxics to achieve the criteria is expected to result in increased economic benefits associated with both direct and passive human use of estuarine and freshwater resources. While time and resource constraints did not permit detailed analysis of all such benefits for the entire State, our analysis includes a comprehensive qualitative discussion of the rule's potential benefits. In addition, we have developed some quantitative evaluations of a subset of benefits, some of which have been monetized.

METHODOLOGIES

Baseline Water Quality Conditions

We estimated baseline water quality conditions for fresh and estuarine waters throughout the State by evaluating California's Water Quality Assessment (WQA) database, developed and maintained by the State Water Resources Control Boards. The WQA is a compilation of data from the State's nine regional Water Quality Control Boards and is organized by region and by waterbody type. It contains a range of information on surface water pollution, including the pollutants that adversely affect water quality in bodies of water that have been evaluated, the sources of pollution, the beneficial uses impaired, and an overall rating of water quality.[1] The State relies on the WQA to develop the biennial water quality report required by §305(b) of the Clean Water Act. We used the 1994 WQA data to evaluate baseline water quality conditions in each of California's nine water regions as well as to evaluate water quality conditions in selected water bodies such as San Francisco Bay, the Bay Delta, the Sacramento River, and the Salton Sea.[2] A summary of the baseline conditions by region is presented in Exhibit 1-1.

---

[1] Currently, not all of California waters are assessed. Approximately 90 percent of all streams and rivers, 23 percent of lakes and reservoirs, and 46 percent of wetlands in the State have not been evaluated for water quality impacts.

[2] Water Quality Assessment, State Water Resources Control Board, 1994. Due to the need for assessment lead time, it was not possible to use updated 1996 information.

Exhibit 1-1

SUMMARY OF CALIFORNIA REGIONAL WATER QUALITY ASSESSMENTS

Region	Areal Extent of Toxics Impairment	Pollutants of Concern	Primary Pollutant Sources	Key Waterbodies Affected	Natural Resources and Beneficial Uses Affected
Region 1: North Coast Region	55% of bays (16,500 acres); minor impairment of other waterbodies	Metals, pesticides	Mix of point sources (municipal and industrial effluent) and nonpoint sources (agriculture and urban runoff)	Arcata Bay, Humboldt Bay	Recreation, municipal supply, wildlife habitat (e.g., salmon); fish spawning and/or migration; rare and endangered species
Region 2: San Francisco Bay	Large areas impaired by toxics, including 70% of bays (200,000 acres); 60% of wetlands (57,000 acres); 39% of rivers (244 miles)	Metals, trace elements, priority organics	Urban runoff and other nonpoint sources affect largest areas; some impairment from municipal and industrial point sources	San Francisco Bay (Lower, Central, South), Suisun Marsh	Recreation, commercial fishing; wildlife habitat, fish migration and/or spawning; rare and endangered species; elevated concentrations of toxics in shellfish, fish, and waterfowl; fish consumption advisories for several waterbodies, including San Francisco Bay, Lake Herman, Guadalupe Reservoir, and others; waterfowl consumption advisory.
Region 3: Central Coast Region	47% of lakes (11,700 acres); 36% of estuaries (1,700 acres); minor impairment of rivers and bays	Metals, pesticides	Agriculture, mining, unspecified nonpoint sources	Morro Bay, Carpinteria Marsh, Elkhorn Slough	Recreation, wildlife habitat; fish consumption advisory for Nacimiento River; fish migration and/or spawning; rare and endangered species
Region 4: Los Angeles Basin	Over 90% of bays and estuaries impaired (16,000 acres); minor impairment of rivers and lakes	Pesticides, priority organics, trace elements	Mix of point sources (municipal treatment, "other" point sources) and nonpoint sources (agriculture, hydrological modification, and urban runoff)	Mugu Lagoon San Gabriel River (lower), Los Angeles River (upper)	Recreation, commercial shellfishing, navigation, wildlife habitat; fish migration and/or spawning; rare and endangered species; fish consumption advisories for Lake Nacimiento and Los Angeles Harbor
Region 5: Central Valley Region	Large areas impaired by toxics, including 100% of estuaries (48,000 acres); 23% of lakes (120,000 acres); 21% of rivers (1,200 miles)	Metals, trace elements	Agriculture, mining; smaller areas affected by municipal treatment, urban runoff, storm sewers, and other nonpoint sources	Delta Waterways, Clear Lake, American River, Feather River, Sacramento River, Grasslands Marshes, Shasta Lake	Municipal supply, agriculture, recreation, wildlife habitat; fish migration and/or spawning; rare and endangered species; fish consumption advisories for Clear Lake, Lake Berryessa, and Grasslands Area; waterfowl consumption advisory for Grasslands Area
Region 6: Lahontan Region	34% of saline lakes (66,000 acres); 19% of lakes (36,000 acres; 13% of rivers (372 miles)	Metals, trace elements, priority organics	Naturally occurring levels of metals and trace elements; lesser areas affected by agriculture, land development, and mining	Eagle Lake, Owens River, Truckee River, Honey Lake	Recreation, municipal supply (exported); fish migration and/or spawning; rare and endangered species

Exhibit 1-1

SUMMARY OF CALIFORNIA REGIONAL WATER QUALITY ASSESSMENTS

Region	Areal Extent of Toxics Impairment	Pollutants of Concern	Primary Pollutant Sources	Key Waterbodies Affected	Natural Resources and Beneficial Uses Affected
Region 7: Colorado River Basin	60% of rivers (1,400 miles) impaired; 220,000 acres of saline lake (Salton Sea)	Pesticides, trace elements	Agriculture	Salton Sea	Recreation, wildlife habitat; rare and endangered species; fish consumption advisory for Salton Sea
Region 8: Santa Ana River Basin	Over 90% of bays and estuaries impaired (4,000 acres); 27% of lakes (4,000 acres)	Metals, pesticides	Primarily nonpoint sources including agriculture, urban runoff, and land development	Upper Newport Bay	Recreation, municipal supply, wildlife habitat, fish spawning and/or migration
Region 9: San Diego Basin	14% of estuaries; minor impairment of other waterbodies	Metals, pesticides, priority organics, trace elements	Estuaries affected by land disposal; other waterbodies affected by diverse mix of point and nonpoint sources	San Diego Bay, Tijuana River Estuary	Recreation, commercial fishing and shellfishing, wildlife habitat, fish spawning and/or migration, rare and endangered species

Source: EPA analysis of 1994 California Water Quality Assessment data base; State of California data on fish and waterfowl consumption advisories. Some key waterbodies impaired by toxics may have changed since the 1994 analysis, but more recent data were not used in the preparation of this report due to time constraints.

It is important to note that information on the extent to which California surface waters currently meet the proposed toxic water quality criteria is incomplete. Water quality conditions in many State waters have not been fully assessed, and assessments of waters that have been evaluated often do not contain monitoring data that is extensive or detailed enough to determine whether the waterbody meets all of the proposed criteria. According to water quality experts from U.S. EPA and the State of California, extrapolating information from the WQA to all waters in the State may create a bias towards overestimating the extent of toxics contamination Statewide. Key assumptions include: assuming that the percentage of toxics impairment found in assessed waters is the same as the percentage of toxic impairment of waters throughout the State; assuming that waters rated as medium impaired waters (those which partially support their uses) were counted together with those rated as poor impaired waters (those which do not support their uses); and that waters listed as impaired in one data base, and associated with toxics in a second data base, were considered waters impaired by toxics.

Although the consensus of the U.S. EPA and State experts is that the above assumptions may create a bias toward overestimating toxics contamination Statewide, these experts also believe that certain other assumptions used in the analysis may create a bias in *underestimating* the extent of toxics contamination. For example, the assumption that the type and scope of all toxics of concern in all State waters appear in the WQA data base may underestimate the extent of toxics impairment because of the infrequency of ambient monitoring throughout the State, or because of the difficulty of detecting the ambient concentrations of certain toxic pollutants when their water quality criteria fall below the minimum detection limit. Consequently, because of all of the uncertainties associated with the WQA data base, State of California and U.S. EPA experts advise against an attempt to quantitatively estimate the magnitude of the bias in either direction.

Human Health

The bioaccumulation of toxic pollutants in aquatic life and water-dependant wildlife can pose a significant health risk to those who eat fish and waterfowl. This is particularly true for recreational or subsistence anglers, who tend to consume greater quantities of fish than the average person and may catch fish from areas that are highly contaminated. A benefit of the proposed rule is a reduction in the concentration of pollutants in fish and waterfowl tissue, with a resulting decrease in risk to

recreational/subsistence anglers and waterfowl hunters. We quantified health benefits for recreational anglers by comparing risks from the consumption of fish under baseline conditions to those that would prevail post-rule.

The calculation of baseline risk (excess cancers and/or non-carcinogenic health effects) was developed using current contaminant levels in fish tissue samples collected from San Francisco Bay and freshwater sport fisheries throughout California. The potential health benefits of the rule have been developed by estimating the potential baseline health risks to anglers consuming contaminated fish, and then comparing these to health risks predicted to occur post-rule, assuming waters meet the CTR criteria based on a cancer risk level of 1×10^{-6} for the general population. Since the State of California has the flexibility to choose criteria based on less stringent cancer risk levels, we also evaluate the potential health benefits to anglers based on a risk level of 1×10^{-5}.

We did not estimate health benefits for subsistence anglers or family members of recreational anglers who might consume contaminated fish. We also were not able to quantify the health benefits associated with consumption of contaminated waterfowl. Finally, we may have underestimated some of the angler human health benefits associated with meeting the CTR criteria because we have not considered the health risks associated with consuming commercially caught fish.

Economic Benefits

From an economic perspective, implementation of water quality programs to achieve the proposed criteria will reduce toxics contamination of aquatic resources in California and will result in avoided costs of illness (cancer and noncancer), and increased protection and restoration of currently affected natural resources that provide valuable services to the 31 million inhabitants of California. These resources support recreational uses such as fishing, wildlife viewing, hiking, hunting, and swimming. These resources also support commercial fishing, serve as sources of drinking water, and provide process and cooling water to industry.

In addition to use values, the total value of an aquatic system also includes values that individuals hold for the resource unrelated to their current use of goods and services provided by the resource. Individuals may value the existence of the aquatic system or the availability of the goods and services provided by the system, even if they do not use the goods and services themselves.

Non-use values may also stem from the desire to preserve the resource for future generations (bequest value) or from a philanthropic sense of environmental responsibility. Reducing toxic contamination to meet the toxic water quality criteria is expected to increase these non-use values.

Economists define the primary economic benefits provided by a natural resource as the sum of individuals' willingness to pay for the services the resource provides, net of any costs associated with enjoying those services. Many natural resource services, however, are not traded in the marketplace and therefore, willingness to pay information cannot be directly obtained from observed behavior. Instead, economists have developed a variety of techniques to value natural resource services, or to estimate the economic benefits of improvements in environmental quality. These methods attempt to determine individuals' willingness to pay for natural resource services directly, through survey research, or indirectly, through the examination of behavior in related markets. They include such techniques as contingent valuation; analysis of added or avoided costs caused by changes in environmental quality; and revealed preference methods, such as travel cost analysis and hedonic property value studies.

While each of these methods was potentially applicable to the California benefits assessment, available resources did not support original research. In lieu of such analysis, we have estimated baseline and post-rule economic benefits using a benefits transfer approach: the application of benefits estimates, contingent valuation studies, functions, data, and/or models developed in other areas to estimate benefits in a similar but alternative context. Specifically, we use the benefit transfer method to value improvements in recreational fishing as well as to estimate non-use values. The benefit transfer method is similar to the approach used by EPA in the Regulatory Impact Analysis for the Agency's Great Lakes Water Quality Guidance, which establishes numeric criteria for toxic pollutants similar to those proposed for California, as well as numerous other economic benefit analyses. In this assessment, where accurate or complete data are not available for each of the water resources evaluated, we have applied as set of reasonable assumptions to obtain lower and upper bound estimates that represent a realistic range of potential benefits likely to occur, rather than developing a single point estimate of benefits.

Ecosystem Benefits

A great proportion of the toxic pollutants addressed in this rule pose relatively high morbidity and mortality risks to both aquatic and aquatic-dependant organisms. Time and data constraints precluded performing site, regional and state-wide quantitative ecological risk assessment for each constituent and water resource covered by today's rule. We therefore evaluated a range of qualitative and quantitative indicators of ecosystem benefits that are likely to accrue from reducing toxic contamination to surface waters and sediments to meet water quality criteria. We utilized data on selected constituent-specific adverse ecological effects at the individual, population, and community level (e.g., decreased direct mortality, reduced breeding success, decreased productivity) that are likely to be occurring in California, as well as site and area-specific data on adverse species impacts. We discuss in somewhat greater detail the ecological benefits expected to accrue in San Francisco Bay and The Salton Sea. In addition, we quantify the areal extent of waters that are likely to experience improvements in ecological quality. These areas include waters that support fish spawning and migration; State and Federal rare, threatened and/or endangered species; and terrestrial and aquatic wildlife. We also estimated the potential hazard for piscivorous wildlife consuming mercury-contaminated fish in selected areas in California based on fish tissue data from throughout the State. Finally, we present and apply one approach for assessing changes in ecological risk associated with potential reductions of copper in parts of the Sacramento River. We do not value or monetize these ecosystem benefits because of the inherent complexity and uncertainty associated with most of the valuation methods.

Apportionment to Point Sources

The benefits estimates in this report represent the total benefits expected to occur once water quality control programs have been fully implemented by California and water quality criteria have been achieved for toxic pollutants. However, the cost analysis for the CTR focused on point sources typically subject to numeric water-quality based NPDES permits. Consequently, EPA did not calculate costs for any program for which it does not have numeric water quality-based effluent limits in effect. Although EPA has focused on calculating costs to NPDES permitted facilities, EPA believes that a comprehensive watershed approach that addresses all significant sources of pollutants will often present more cost-effective approaches. Because EPA is developing estimates of costs

associated with implementation of the proposed water quality criteria, it is important to estimate the benefits specifically associated with reducing toxic discharges from point sources. This will allow a more consistent comparison of costs and benefits.

To apportion benefits to point sources, we first use available data to estimate the percent of all toxics loadings coming from point sources. We then adjust this figure by the percentage reduction in point source loadings expected to occur when the toxics criteria are fully implemented by the state (based on the cost analysis for the proposed rule). Finally, we use this information to scale the health, economic, and ecological benefits developed in earlier chapters.

Throughout the apportionment analysis, we define point sources to include NPDES permitted sources -- publicly owned treatment works (POTWs), industrial dischargers, and active/inactive mines.[3] Although stormwater discharges are regulated as a point source, they are not included as a point source category in this analysis because they are not explicitly addressed in the available data and because they are typically not subject to numeric water quality-based effluent limits. Although data sources vary, "other" sources generally include urban runoff, runoff from forestry and agriculture, rangeland runoff, and atmospheric deposition.

RESULTS

Human Health Benefits

We estimate that human health risks associated with anglers eating contaminated sport fish may be reduced substantially if health risk target levels associated with proposed water quality criteria in California fisheries are achieved. These benefits would accrue to the estimated 125,000

[3] While mines are considered to be a point source subject to NPDES under the Clean Water Act, not all mines in California have been permitted. Loadings reductions for mines (both active and inactive) with major NPDES permits have been estimated, and are used in this analysis, although they do not represent the entire universe of mines in the State. Consequently, some of the benefits described here may not occur in the same time frame as benefits associated with other point sources evaluated (POTWs and industrial dischargers).

anglers fishing in San Francisco Bay and 2.2 million freshwater anglers. Similar population benefits may accrue for an additional 500,000 to 600,000 saltwater anglers in other California estuaries, but specific risk estimates for these anglers were not calculated.

Summary of Potential Cancer Health Benefits to Anglers

Our analysis of human health risks based on a risk level of 1×10^{-6} for the general population supports the following conclusions:

- Cancer risks for freshwater anglers would be reduced by 91 percent.
- The population cancer risk for freshwater anglers would decrease from between 5 and 11 cases per year to approximately one case per year.
- Freshwater anglers would have a post-rule individual excess lifetime cancer risk ranging from 1.4×10^{-5} to 3.3×10^{-5} for typical fish consumption.
- Cancer risks for San Francisco Bay anglers would be reduced by 91 percent.
- The population cancer risk for Bay area anglers would decrease from the baseline of one or fewer cases per year to zero cases per year.
- San Francisco Bay anglers would have a post-rule individual excess lifetime cancer risk ranging from 1.7×10^{-5} to 3.8×10^{-5} for typical fish consumption.

Summary of Potential Noncancer Health Benefits

Our analysis of human health non-cancer risks for the general population supports the following conclusions:

- Noncancer risks for freshwater anglers would be reduced by 67 percent.
- The hazard index for freshwater anglers would decrease from the baseline of 2.3 to 5.4 to less than 0.8 to 1.8 for typical fish consumption.
- Mercury would have the highest post-rule hazard quotient for an individual freshwater contaminant -- 0.6 to 1.4 for typical consumption.
- Non-cancer risks for San Francisco Bay anglers would be reduced by 76 percent.
- The hazard index for Bay area anglers would decrease from the baseline of 3.5 to 8.2 to less than 0.9 to 2.0 for typical fish consumption.
- Mercury would have the highest post-rule hazard quotient for an individual San Francisco Bay contaminant -- 0.8 to 1.7 for typical consumption.

Uncertainties

The analysis of angler health risks involves a series of assumptions that are generally designed to characterize typical recreational anglers. To the extent that anglers differ from this characterization, the analysis may over- or underestimate risk. Some of the areas of potential uncertainty include consumption rates, mixing of species in an individual's diet, and assigning concentration values to contaminants in samples in which they were below detection. We addressed these issues by developing ranges of potential exposure values. In the case of consumption rates,

we present results based on reasonable bounds for typical consumption and for 90th percentile consumption. With respect to species mixing and nondetected values, we have conducted sensitivity analyses to characterize the magnitude of these uncertainties.

Other uncertainties, especially those affecting subpopulations, could not be fully characterized within this analysis. These include ethnic and income effects on consumption rates, fish preparation methods, and risks to family members. We reviewed our standard assumptions against information provided in the relevant literature on angler subpopulations to determine the potential effects each of these uncertainties has on the analysis.

Finally, we may have underestimated some of the angler human health benefits associated with meeting CTR criteria because we have not considered the health risks associated with consuming commercially caught fish. California has commercial fisheries in water bodies covered by this rule, and it is likely that achievement of the CTR criteria will result in some reduced toxic contamination of commercial fisheries. However, because of difficulties in estimating the number of exposed individuals as well as difficulties in linking toxic contamination solely to California sources, we were not able to estimate the baseline health risks and benefits associated with meeting CTR criteria.

Economic Benefits

The economic benefits associated with meeting toxic water quality criteria are significant, and include multiple use and non-use components. Exhibit 1-2 summarizes these results. Key findings include the following:

- Monetized benefits associated with achieving toxic water quality criteria established by the CTR are estimated for recreational fishing, human health cancer effects, and passive use values only. These benefits are significant, ranging from a low of $62 million per year to an upper bound of approximately $600 million per year.

- Recreational fishing benefits are valued at between $35 and $196 million per year. Related non-use benefits are estimated to be $17 to $294 million. Finally, avoided cancer deaths are valued at between $10 and $110 million per year.

EXHIBIT 1-2

SUMMARY OF POTENTIAL ANNUAL BENEFITS ASSOCIATED WITH ACHIEVING WATER QUALITY STANDARDS ESTABLISHED BY THE CALIFORNIA TOXICS RULE

Benefit Category	Total Benefits (Millions $1996)(1)(2)	Point Source Benefits (Millions $1996)(1)(2)(3)
USE VALUES		
Improved Recreational Fishing	$35 - $196	$2 - $26
Improved Recreational Hunting	$ - Not Estimated	$ – Not Estimated
Improved Water Enhanced Recreation	$ – Not Estimated	$ – Not Estimated
Improved Commercial Fisheries	$ – Not Estimated	$ – Not Estimated
Drinking Water and Sludge Treatment Savings	$ – Not Estimated	$ – Not Estimated
Improved Property Values	$ – Not Estimated	$ – Not Estimated
Avoided Cost of endangered species management and associated land use restrictions	$ – Not Estimated	$ – Not Estimated
Human Health (4)		
Reduced cancer risk – anglers	$10 – $110; 91% reduction in individual excess lifetime risk	$ – Not Estimated reduction in individual excess lifetime risk
Reduced non-cancer risk – anglers	67% - 76% reduction in non-cancer risk; $ – Not Estimated	reduction in non-cancer risk; $ – Not Estimated
Reduced health risk to some subsistence anglers	$ – Not Estimated	$ – Not Estimated
NON-USE		
Bequest and Existence Values	$17 – $294	$1 – $39
Ecological		
Reduced morbidity/mortality to aquatic and terrestrial wildlife; Improved integrity of aquatic and aquatic-dependent ecosystems	- 815,000 acres of bays, harbors, estuaries, lakes, and wetlands - 4,000 miles of rivers	- 20,000 acres of bays, harbors, estuaries, lakes and wetlands - 133 miles of rivers
Improved conditions in habitat supporting fish spawning/migration	- 227,000 acres of bays, harbors and estuaries - 102,000 acres of lakes - 11,000 acres of saline lakes - 1,000 miles of rivers	- 14,000 acres of bays, harbors and estuaries - 5,000 acres of lakes - 53 miles of rivers
Improved conditions in habitat supporting threatened and endangered species	- 180,000 acres of bays, harbors and estuaries - 230,000 acres saline lakes - 1,900 miles of rivers	- 10,000 acres of bays, harbors, and estuaries - 1,700 acres of lakes - 100 miles of rivers
TOTAL	**$62 - $600 + $ Benefits Not Estimated**	**$3 - $65 +$ Benefits Not Estimated**

(1) Dollars converted to first quarter 1996 using Gross Domestic Product implicit price deflator.
(2) $ – Not Estimated = Dollar benefits expected to accrue, but not yet monetized.
(3) Point Sources are defined as POTWs and industrial NPDES dischargers.
(4) Health risks estimated for 80 percent of California anglers.

- A number of other economic benefits are expected to accrue when water quality criteria are met. However, we have not quantified or monetized these comprehensively. They include: increased value for commercial fishing; drinking water treatment, sludge treatment, and dredged material management cost savings; increased property values; increased value and participation in recreational hunting and other near-stream activities; avoided cost of illness associated with consumption of commercially caught seafood; and avoided costs of endangered species management.

These findings are subject to some uncertainty given the limited availability of Statewide data and the overall benefits transfer methodology approach used. First, we assume that the condition of asessed waters in California is representative of conditions in all assessed resources. If conditions are considerably worse or better in these unassessed waters, then benefits estimates are likely to be higher or lower than those presented here. Currently, EPA and State water quality experts agree that because of all of the uncertainties in the WQA data base (both in underestimating and overestimating waters that are adversely affected by toxics) it is not possible to quantitatively or qualitatively estimate the magnitude of the bias in either direction. Second, estimation of the increased value of current angling and increased participation in recreational angling assumes that anglers have not substituted away from contaminated waters. It is likely that some anglers are substituting away from contaminated waters, causing some of the angler benefits to be overstated. Alternatively, fishing effort may be disproportionately concentrated on impaired waters because of the proximity of the waters to population centers, resulting in an understatement of angling benefits. Because we have not done a waterbody-by-waterbody evaluation of substitute fishing areas and angler substitution behavior, we cannot estimate the direction or degree of bias of our estimates.

Third, the approach used here assumes that reductions in toxic loadings and the resulting benefits are linearly related. This may not be true under certain circumstances, although the direction of the bias introduced is unclear. Fourth, the monetized estimate of benefits omits several categories of benefits that are expected to accrue, resulting in a potentially significant underestimation of total economic benefits. Finally, the persistence and toxicity of the pollutants covered by the criteria have important implications for all parts of the benefits analysis. Because some of these compounds (e.g. dioxins, mercury) may persist in various waters, sediment, and animal tissue for years after toxic discharges have been reduced, a portion of the benefits described here may not be realized immediately.

Ecological

The ecological benefits associated with achieving the criteria in all California waters are significant. Large areas of water resources in every region of the state currently are adversely affected by toxics. Reducing toxic loadings to meet criteria will lead to healthier and more stable organisms, ecological populations, and ecological communities. Exhibit 1-3 summarizes these overall benefits. Specific findings of the ecological benefits analysis include the following:

- Toxics driving ecological benefits include copper, silver, zinc, cadmium, chromium, PCBs, selenium, mercury, and estrogenic pesticides (e.g., endosulfan). These latter four contaminants can bioaccumulate, and pose an additional threat to fish and wildlife throughout the State.

- Reducing loadings of contaminants to meet criteria levels may contribute to improved stability, resilience and overall integrity of organisms, populations, and communities living in or dependant on more than 800,000 acres of assessed bays, estuaries, lakes, and wetlands and more than 4,000 miles of rivers that are now currently affected.

- Reduced toxic loadings are expected to contribute to improved conditions for fish spawning and/or migration in more than 227,000 acres of bays, harbors, and estuaries; 102,000 acres of lakes; 1,000 miles of rivers and streams; and 11,000 acres of saline lakes.

EXHIBIT 1-3

ECOLOGICAL BENEFITS OF THE CALIFORNIA TOXICS RULE

Toxic of Concern	Selected Documentation in California Waters, Sediments and/or Biota	Potential Beneficial Effects to Individual Organisms When Toxic Reduced to Meet Water Quality Criteria
Arsenic	Endangered species, mussels, fish, sediments, water	Improved growth and survival; Improved reproduction; Improved physiology; Increased resistance to infection; Reduced mutagenic, teratogenic, carcinogenic effects.
Cadmium	Endangered species, mussel, fish, bird, seal, waterfowl sediments, water	Improved growth and survival; Improved reproduction; Reduced mutagenic, teratogenic, carcinogenic effects.
Chromium (III and VI)	Striped bass, mussel, clam, fish, sediments, water	Improved growth and survival; Improved reproduction; Reduced mutagenic, teratogenic, carcinogenic effects.
Copper	Endangered species, striped Bass, mussel, clam, fish, bird, seal, sediments, water	Improved growth and survival; Improved reproduction
Lead	Endangered species, mussel, fish, bird, seal, sediments, water	Improved metabolism.
Mercury	Endangered species, striped bass, mussel, fish, bird, seal, (piscivorous wildlife) sediments, water	Improved growth and survival; Improved reproduction; Improved development; Improved metabolism;
Nickel	Striped bass, mussel, fish, bird, seal, sediments, water	Improved growth and survival; Improved reproduction; Improved development; Improved metabolism
Selenium	Endangered species, mussel, clam, fish, bird, seal, waterfowl, (piscivorous animals) sediments, water	Improved growth and survival; Improved reproduction; Improved development; Improved behavior; Reduced mutagenic, teratogenic, carcinogenic effects.
Silver	Endangered species, mussel, clam, fish, striped bass, bird, sediments, water	Improved growth and survival; Improved reproduction; Reduced carcinogenic effects.
Zinc	Endangered species, striped bass, mussel, fish, bird, sediments, water	Improved growth and survival; Improved reproduction; Improved behavior; Improved physiology
Dioxins	Endangered species, wildlife, fish, piscivorous animals, waterfowl	Improved growth and survival; Improved reproduction; Improved physiology
Endosulfan and Other Estrogenic Pesticides (1)	Endangered species, fish, striped bass, birds, waterfowl, water, sediments	Improved growth and survival; Improved physiology Improved reproduction.

Toxic of Concern	Selected Documentation in California Waters, Sediments and/or Biota	Potential Beneficial Effects to Individual Organisms When Toxic Reduced to Meet Water Quality Criteria
Polycyclic Aromatic Hydrocarbons (PAHs)	Mussel, fish, sediments, water	Improved growth and survival; Improved reproduction; Improved immunity; Reduced mutagenic, teratogenic and carcinogenic effects.
Polychlorinated Biphenyls (PCBs)	Endangered species, starry flounder, black-crowned night heron, mussel, seal, waterfowl, striped bass, piscivorous wildlife, sediments, water	Improved growth and survival; Improved reproduction; Improved behavior; Improved immunity; Reduced mutagenic, teratogenic, carcinogenic effects.

(1) Estrogenic pesticides are those that are associated with the disruption of normal endocrine and reproductive functions. Estrogenic pesticides include banned pesticides like DDT and toxaphene, as well as currently-used pesticides, such as Endosulfan.

Sources: Brown, 1996; California Environmental Protection Agency, State Water Resources Control Board, 1994; Department of Fish and Game, State of California, 1991; Fry, 1996; Harvey, et al., 1992; Herbold, et al., 1992; Kopec and Harvey, 1995; Larry Walker Associates, 1992; Ohlendorf and Fleming, 1988; Pease, 1995; Schwarzback, et al., 1996; Setzler-Hamilton, et al., 1988; Smith and Flegal, 1993; Solomon et al., 1996; Thompson, 1996; U.S. EPA, 1985a; U.S. EPA, 1992; U.S. Fish and Wildlife Service, 1997; U.S.G.S., 1990; U.S.G.S., 1993

Population	Community	Ecosystem
Increased Health	Improved Species Diversity and Composition	Improved System Stability
Improved Genetic Diversity	Enhanced Population Stability	Increased Community Resilience
Improved Recruitment	Maintain species assemblages	Improved Community Diversity
Increased Abundance	Improved food web supply and diversity Increased and improved productivity	Improved Biodiversity

Ecosystem: A functional system consisting of the living biotic community and the physical environment, comprised of all living organisms, their remains, and the minerals, chemicals and resources on which they depend for their survival and reproduction.

Community: An assemblage of populations living in a prescribed area or physical habitat that have a functional and compositional unity; may be relatively independent or dependent on neighboring assemblages.

Population: A group of organisms of the same species, generally occupying a contiguous area, and capable of interbreeding.

- Statewide, threatened and endangered species may be at risk from toxics in approximately 180,000 acres of bays, harbors and estuaries, 1,900 river miles, and 230,000 acres of saline lakes. Reducing toxic contaminants to criteria levels is expected to help contribute to improved conditions for the successful recovery of threatened and endangered species including species such as the Delta smelt, Desert pupfish, California brown pelican, Bald eagle, California clapper rail, California tiger salamander, and western snowy plover.

- Mercury concentrations in California fish are estimated to reach levels that may be hazardous to piscivorous wildlife.[4] Adverse effects on wildlife are also occurring as a result of exposure to selenium.

- The aquatic and terrestrial wildlife of the San Francisco Bay watershed and the Central Valley are expected show the greatest improvement relative to other regions because of the extent of current toxic loadings and the diversity and richness of species, populations, and communities potentially affected by toxics.

- Reduced concentrations of both selenium and pesticides in the waters that feed the Salton Sea are expected to contribute to the restoration and maintenance of some populations of wildlife, including threatened and endangered species. However, current selenium criteria may not be stringent enough to adequately protect some aquatic-dependent wildlife species.

- Reducing copper discharges to the Sacramento River to meet water quality criteria would result in substantial protection for 90 percent or more of the organisms and communities that are currently adversely affected.

- Because all components of the ecosystem are linked, we expect that reducing toxic discharges will contribute to reduced morbidity/mortality of individual organisms, may help to contribute to the increased stability, resilience and overall integrity of numerous ecosystems throughout the State, and may contribute to restoring and maintaining California's rich biodiversity.

---

[4] Piscivorous wildlife are birds, fish, mammals, and other animals that eat fish.

Apportioning Benefits to Point Sources

To apportion the benefits of implementing the California Toxics Rule criteria to point source dischargers, we reviewed regional loadings studies to determine how point sources contribute to total loadings of priority toxic pollutants throughout the State. Then we apportioned economic benefits to point sources using point source contribution estimates averaged across the key pollutants controlled. We then quantitatively discussed apportionment of recreational angler health benefits to point sources, and examined key pollutants and analytical obstacles that preclude a strict quantitative apportionment of risks from cancer and noncancer. Finally, we apportioned ecological benefits based on qualitative and quantitative ecological assessments. Our conclusions are as follows:

- Point sources such as POTWs, industrial dischargers, and mines are significant contributors of total toxic pollutants discharged to California surface waters, although other sources (e.g., urban runoff, agricultural runoff) tend to be more significant.

- Point sources are responsible for a large share of toxics loadings to California bays. For bays other than San Francisco Bay, we estimate that point sources account for between 42 and 64 percent of toxics loadings. Point sources account for between five and 30 percent of toxics loadings to freshwater, and between four and 11 percent of loadings to San Francisco Bay.

- We estimate that control of toxics discharged from point sources will yield between $3 million and $65 million per year in economic benefits (recreational fishing and non-use values), with a midpoint estimate of about $34 million per year.

- Apportioning health risks to point sources is difficult because a number of the most significant pollutants occur in concentrations below detection limits; this precludes tracing the pollutants to point sources and other sources. However, examination of effluent data and literature, as well as discussions with knowledgeable regulatory staff, suggests that a number of health risk drivers -- PCBs, dioxin, pesticides, and mercury -- are discharged, at least in part, by point sources. Despite this finding, representative calculations suggest that the potential health risk reductions associated with control of point sources are likely to be limited unless additional effluent reductions are achieved.

- Point source discharge reductions are likely to yield a number of ecological benefits as well. First, reduced loadings will reduce morbidity/mortality of aquatic and some terrestrial wildlife and improve the integrity of ecosystems in at least 20,000 acres of assessed bays, estuaries, lakes, and wetlands as well as 100 miles of miles of rivers that are now currently impaired. Reduced point source loadings may also improve conditions for fish spawning and/or migration in about 14,000 acres of bays, harbors, and estuaries; 5,000 acres of lakes; and 50 miles of rivers and streams. Finally, reductions in point source contributions of toxics are expected to improve habitat supporting threatened and endangered species in about 10,000 acres of bays, harbors and estuaries; 1,700 acres of lakes; and 100 river miles.

- Improved water quality resulting from point source controls implemented to meet the CTR criteria, and the associated improvements in survival, growth, and reproductive capacity of aquatic and aquatic-dependent organisms, will contribute to the increased stability, resilience, and overall health of numerous ecosystems throughout California, and may contribute to protecting, restoring, and maintaining California's rich biodiversity.

These findings are subject to some uncertainty given the limited availability of Statewide data and the overall limitations of the apportionment approach used. First, the extent and diversity of surface water resources and the great number and variety of dischargers make it difficult to draw general conclusions regarding the relative influence of point sources and nonpoint sources discharging to California waters. While available data provide enough information to estimate broad ranges of benefits associated with reducing toxic discharges from point sources throughout the state, the

circumstances at a specific waterbody may differ from these general estimates. Second, the apportionment approach used here assumes that reductions in toxic loadings and the resulting benefits are linearly related. This may not be true undercertain circumstances, although the direction of the bias introduced is unclear.

JUNE 1997

Attachment 1:

CRITERIA FOR PRIORITY TOXIC POLLUTANTS IN THE STATE OF CALIFORNIA

PART 131 - WATER QUALITY STANDARDS

SUBPART D - [Amended]

1. Section 131.38 is added to subpart D to read as follows:

§131.38 Establishment of Numeric Criteria for Priority Toxic Pollutants for the State of California.

(a) Scope. This section is a general promulgation of criteria for priority toxic pollutants in the State of California for inland surface waters and enclosed bays and estuaries. This section also contains a compliance schedule provision.

(b)(1) Criteria for Priority Toxic Pollutants in the State of California.

A		B		C		D	
		FRESHWATER		SALTWATER		HUMAN HEALTH For Consumption of:	
Compound	CAS Number	CMC d (ug/L) B1	CCC d (ug/L) B2	CMC d (ug/L) C1	CCC d (ug/L) C2	Water & Organisms (ug/L) D1	Organisms Only (ug/L) D2
1. Antimony	7440360					14 a,s	4300 a,t
2. Arsenic	7440382	340 i,m,w	150 i,m,w	69 i,m	36 i,m		
3. Beryllium	7440417					n	n
4. Cadmium	7440439	4.3 e,i,m, w,x	2.2 e,i,m, w	42 i,m	9.3 i,m	n	n
5a. Chromium (III)	16065831	550 e,i,m, o	180 e,i,m, o			n	n
5b. Chromium (VI)	18540299	16 i,m,w	11 i,m,w	1100 i,m	50 i,m	n	n
6. Copper	7440508	13 e,i,m, w,x	9.0 e,i,m, w	4.8 i,m	3.1 i,m	1300	
7. Lead	7439921	65 e,i,m	2.5 e,i,m	210 i,m	8.1 i,m	n	n
8. Mercury	7439976	1.4 i,m,w	0.77 i,m,w	1.8 i,m	0.94 i,m	0.050 a	0.051 a
9. Nickel	7440020	470 e,i,m, w	52 e,i,m, w	74 i,m	8.2 i,m	610 a	4600 a
10. Selenium	7782492	p	5.0 q	290 i,m	71 i,m	n	n
11. Silver	7440224	3.4 e,i,m		1.9 i,m			
12. Thallium	7440280					1.7 a,s	6.3 a,t
13. Zinc	7440666	120 e,i,m, w,x	120 e,i,m, w	90 i,m	81 i,m		
14. Cyanide	57125	22 o	5.2 o	1 r	1 r	700 a	220,000 a,j

A		B		C		D	
		FRESHWATER		SALTWATER		HUMAN HEALTH For Consumption of:	
Compound	CAS Number	CMC d (ug/L) B1	CCC d (ug/L) B2	CMC d (ug/L) C1	CCC d (ug/L) C2	Water & Organisms (ug/L) D1	Organisms Only (ug/L) D2
15. Asbestos	1332214					7,000,000 fibers/L k,s	
16. 2,3,7,8 Tetrachloro-dibenzo-p-dioxin (TCDD or Dioxin)	1746016					0.000000013 c	0.000000014 c
17. Acrolein	107028					320 s	780 t
18. Acrylonitrile	107131					0.059 a,c,s	0.66 a,c,t
19. Benzene	71432					1.2 a,c	71 a,c
20. Bromoform	75252					4.3 a,c	360 a,c
21. Carbon Tetrachloride	56235					0.25 a,c,s	4.4 a,c,t
22. Chlorobenzene	108907					680 a,s	21,000 a,j,t
23. Chlorodibromomethane	124481					0.41 a,c	34 a,c
24. Chloroethane	75003						
25. 2-Chloroethylvinyl Ether	110758						
26. Chloroform	67663					5.7 a,c	470 a,c
27. Dichlorobromomethane	75274					0.56 a,c	46 a,c
28. 1,1-Dichloroethane	75343						

A		B		C		D	
		FRESHWATER		SALTWATER		HUMAN HEALTH For Consumption of:	
Compound	CAS Number	CMC d (ug/L) B1	CCC d (ug/L) B2	CMC d (ug/L) C1	CCC d (ug/L) C2	Water & Organisms (ug/L) D1	Organisms Only (ug/L) D2
29. 1,2-Dichloroethane	107062					0.38 a,c,s	99 a,c,t
30. 1,1-Dichloroethylene	75354					0.057 a,c,s	3.2 a,c,t
31. 1,2-Dichloropropane	78875					0.52 a	39 a
32. 1,3-Dichloropropylene	542756					10 a,s	1,700 a,t
33. Ethylbenzene	100414					3,100 a,s	29,000 a,t
34. Methyl Bromide	74839					48 a	4,000 a
35. Methyl Chloride	74873					n	n
36. Methylene Chloride	75092					4.7 a,c	1,600 a,c
37. 1,1,2,2-Tetrachloroethane	79345					0.17 a,c,s	11 a,c,t
38. Tetrachloroethylene	127184					0.8 c,s	8.85 c,t
39. Toluene	108883					6,800 a	200,000 a
40. 1,2-Trans-Dichloroethylene	156605					700 a	140,000 a

A		B		C		D	
		FRESHWATER		SALTWATER		HUMAN HEALTH For Consumption of:	
Compound	CAS Number	CMC d (ug/L) B1	CCC d (ug/L) B2	CMC d (ug/L) C1	CCC d (ug/L) C2	Water & Organisms (ug/L) D1	Organisms Only (ug/L) D2
41. 1,1,1-Trichloroethane	71556					n	n
42. 1,1,2-Trichloroethane	79005					0.60 a,c,s	42 a,c,t
43. Trichloroethylene	79016					2.7 c,s	81 c,t
44. Vinyl Chloride	75014					2 c,s	525 c,t
45. 2-Chlorophenol	95578					120 a	400 a
46. 2,4-Dichlorophenol	120832					93 a,s	790 a,t
47. 2,4-Dimethylphenol	105679					540 a	2,300 a
48. 2-Methyl- 4,6-Dinitrophenol	534521					13.4 s	765 t
49. 2,4-Dinitrophenol	51285					70 a,s	14,000 a,t
50. 2-Nitrophenol	88755						
51. 4-Nitrophenol	100027						
52. 3-Methyl 4-Chlorophenol	59507						

A		B		C		D	
		FRESHWATER		SALTWATER		HUMAN HEALTH For Consumption of:	
Compound	CAS Number	CMC d (ug/L) B1	CCC d (ug/L) B2	CMC d (ug/L) C1	CCC d (ug/L) C2	Water & Organisms (ug/L) D1	Organisms Only (ug/L) D2
53. Pentachlorophenol	87865	19 f,w	15 f,w	13	7.9	0.28 a,c	8.2 a,c,j
54. Phenol	108952					21,000 a	4,600,000 a,j,t
55. 2,4,6-Trichlorophenol	88062					2.1 a,c	6.5 a,c
56. Acenaphthene	83329					1,200 a	2,700 a
57. Acenaphthylene	208968						
58. Anthracene	120127					9,600 a	110,000 a
59. Benzidine	92875					0.00012 a,c,s	0.00054 a,c,t
60. Benzo(a)Anthracene	56553					0.0044 a,c	0.049 a,c
61. Benzo(a)Pyrene	50328					0.0044 a,c	0.049 a,c
62. Benzo(b)Fluoranthene	205992					0.0044 a,c	0.049 a,c
63. Benzo(ghi)Perylene	191242						
64. Benzo(k)Fluoranthene	207089					0.0044 a,c	0.049 a,c

A		B		C		D	
		FRESHWATER		SALTWATER		HUMAN HEALTH	
						For Consumption of:	
Compound	CAS Number	CMC d (ug/L) B1	CCC d (ug/L) B2	CMC d (ug/L) C1	CCC d (ug/L) C2	Water & Organisms (ug/L) D1	Organisms Only (ug/L) D2
65. Bis(2-Chloroethoxy)Methane	111911						
66. Bis(2-Chloroethyl)Ether	111444					0.031 a,c,s	1.4 a,c,t
67. Bis(2-Chloroisopropyl)Ether	108601					1,400 a	170,000 a,t
68. Bis(2-Ethylhexyl)Phthalate	117817					1.8 a,c,s	5.9 a,c,t
69. 4-Bromophenyl Phenyl Ether	101553						
70. Butylbenzyl Phthalate	85687					3000 a	5200 a
71. 2-Chloronaphthalene	91587					1,700 a	4,300 a
72. 4-Chlorophenyl Phenyl Ether	7005723						
73. Chrysene	218019					0.0044 a,c	0.049 a,c
74. Dibenzo(a,h)Anthracene	53703					0.0044 a,c	0.049 a,c
75. 1,2 Dichlorobenzene	95501					2,700 a	17,000 a
76. 1,3 Dichlorobenzene	541731					400	2,600

A		B		C		D	
		FRESHWATER		SALTWATER		HUMAN HEALTH For Consumption of:	
Compound	CAS Number	CMC d (ug/L) B1	CCC d (ug/L) B2	CMC d (ug/L) C1	CCC d (ug/L) C2	Water & Organisms (ug/L) D1	Organisms Only (ug/L) D2
77. 1,4 Dichlorobenzene	106467					400	2,600
78. 3,3 Dichlorobenzidine	91941					0.04 a,c,s	0.077 a,c,t
79. Diethyl Phthalate	84662					23,000 a,s	120,000 a,t
80. Dimethyl Phthalate	131113					313,000 s	2,900,000 t
81. Di-n-Butyl Phthalate	84742					2,700 a,s	12,000 a,t
82. 2,4-Dinitrotoluene	121142					0.11 c,s	9.1 c,t
83. 2,6-Dinitrotoluene	606202						
84. Di-n-Octyl Phthalate	117840						
85. 1,2-Diphenylhydrazine	122667					0.040 a,c,s	0.54 a,c,t
86. Fluoranthene	206440					300 a	370 a
87. Fluorene	86737					1,300 a	14,000 a
88. Hexachlorobenzene	118741					0.00075 a,c	0.00077 a,c

A		B		C		D	
		FRESHWATER		SALTWATER		HUMAN HEALTH For Consumption of:	
Compound	CAS Number	CMC d (ug/L) B1	CCC d (ug/L) B2	CMC d (ug/L) C1	CCC d (ug/L) C2	Water & Organisms (ug/L) D1	Organisms Only (ug/L) D2
89. Hexachlorobutadiene	87683					0.44 a,c,s	50 a,c,t
90. Hexachlorocyclopentadiene	77474					240 a,s	17,000 a,j,t
91. Hexachloroethane	67721					1.9 a,c,s	8.9 a,c,t
92. Indeno(1,2,3-cd)Pyrene	193395					0.0044 a,c	0.049 a,c
93. Isophorone	78591					8.4 c,s	600 c,t
94. Naphthalene	91203						
95. Nitrobenzene	98953					17 a,s	1,900 a,j,t
96. N-Nitrosodimethylamine	62759					0.00069 a,c,s	8.1 a,c,t
97. N-Nitrosodi-n-Propylamine	621647					0.005 a	1.4 a
98. N-Nitrosodiphenylamine	86306					5.0 a,c,s	16 a,c,t
99. Phenanthrene	85018						
100. Pyrene	129000					960 a	11,000 a

A		B		C		D	
		FRESHWATER		SALTWATER		HUMAN HEALTH For Consumption of:	
Compound	CAS Number	CMC d (ug/L) B1	CCC d (ug/L) B2	CMC d (ug/L) C1	CCC d (ug/L) C2	Water & Organisms (ug/L) D1	Organisms Only (ug/L) D2
101. 1,2,4-Trichlorobenzene	120821						
102. Aldrin	309002	3 g		1.3 g		0.00013 a,c	0.00014 a,c
103. alpha-BHC	319846					0.0039 a,c	0.013 a,c
104. beta-BHC	319857					0.014 a,c	0.046 a,c
105. gamma-BHC	58899	0.95 g,w		0.16 g		0.019 c	0.063 c
106. delta-BHC	319868						
107. Chlordane	57749	2.4 g	0.0043 g	0.09 g	0.004 g	0.00057 a,c	0.00059 a,c
108. 4,4'-DDT	50293	1.1 g	0.001 g	0.13 g	0.001 g	0.00059 a,c	0.00059 a,c
109. 4,4'-DDE	72559					0.00059 a,c	0.00059 a,c
110. 4,4'-DDD	72548					0.00083 a,c	0.00084 a,c
111. Dieldrin	60571	0.24 g,w	0.056 g,w	0.71 g	0.0019 g	0.00014 a,c	0.00014 a,c
112. alpha-Endosulfan	959988	0.22 g	0.056 g	0.034 g	0.0087 g	110 a	240 a
113. beta-Endosulfan	33213659	0.22 g	0.056 g	0.034 g	0.0087 g	110 a	240 a
114. Endosulfan Sulfate	1031078					110 a	240 a

A		B		C		D	
		FRESHWATER		SALTWATER		HUMAN HEALTH	
Compound	CAS Number	CMC d (ug/L) B1	CCC d (ug/L) B2	CMC d (ug/L) C1	CCC d (ug/L) C2	For Consumption of: Water & Organisms (ug/L) D1	Organisms Only (ug/L) D2
115. Endrin	72208	0.086 g,w	0.036 g,w	0.037 g	0.0023 g	0.76 a	0.81 a,j
116. Endrin Aldehyde	7421934					0.76 a	0.81 a,j
117. Heptachlor	76448	0.52 g	0.0038 g	0.053 g	0.0036 g	0.00021 a,c	0.00021 a,c
118. Heptachlor Epoxide	1024573	0.52 g	0.0038 g	0.053 g	0.0036 g	0.00010 a,c	0.00011 a,c
119.- 125. Polychlorinated biphenyls (PCBs)			0.014 g,u		0.03 g,u	0.00017 v	0.00017 v
126. Toxaphene	8001352	0.73	0.0002	0.21	0.0002	0.00073 a,c	0.00075 a,c
TOTAL NUMBER OF CRITERIA (h):		24	28	23	27	99	97

FOOTNOTES:

a. These criteria have been revised to reflect the Agency q1* or RfD, as contained in the Integrated Risk Information System (IRIS) as of October 1, 1996. The fish tissue bioconcentration factor (BCF) from the 1980 documents was retained in each case.

b. This letter is not used as a footnote.

c. These criteria are based on carcinogenicity of 10 (-6) risk.

d. The Criteria Maximum Concentration (CMC) equals the highest concentration of a pollutant to which aquatic life can be exposed for a short period of time without deleterious effects. Criteria Continuous Concentration (CCC) equals the highest concentration of a pollutant to which aquatic life can be exposed for an extended period of time (4 days) without deleterious effects. ug/l equals micrograms per liter.

e. These freshwater aquatic life criteria for metals are expressed as a function of total hardness (mg/l) in the water body. The equations are provided in matrix at §131.38(b)(2). Values displayed above in the matrix correspond to a total hardness of 100 mg/l.

f. These freshwater aquatic life criteria for pentachlorophenol are expressed as a function of pH, and are calculated as follows: Values displayed above in the matrix correspond to a pH of 7.8. CMC = exp(1.005(pH) - 4.830). CCC = exp(1.005(pH) - 5.290).

g. These aquatic life criteria for these compounds were issued in 1980 utilizing the 1980 Guidelines for criteria development. The acute values shown are final acute values (FAV) which by the 1980 Guidelines are instantaneous values as contrasted with a CMC which is a short-term average.

h. These totals simply sum the criteria in each column. For aquatic life, there are 30 priority toxic pollutants with some type of freshwater or saltwater, acute or chronic criteria. For human health, there are 100 priority toxic pollutants with either "water + organism" or "organism only" criteria. Note that these totals count chromium as one pollutant even though EPA has developed criteria based on two valence states. In the matrix, EPA has assigned numbers 5a and 5b to the criteria for chromium to reflect the fact that this list of 126 priority pollutants includes only a single listing for chromium.

i. Criteria for these metals are expressed as a function of the water-effect ratio, WER, as defined in 40 CFR 131.38(c). CMC = column B1 or C1 value x WER; CCC = column B2 or C2 value x WER.

j. No criteria for protection of human health from consumption of aquatic organisms (excluding water) was presented in the 1980 criteria document or in the 1986 Quality Criteria for Water. Nevertheless, sufficient information was presented in the 1980 document to allow a calculation of a criterion, even though the results of such a calculation were not shown in the document.

k. This criterion for asbestos is the MCL (56 FR 3526, January 30, 1991).

l. This letter is not used as a footnote.

m. These freshwater and saltwater criteria for metals are expressed in terms of the dissolved fraction of the metal in the water column. Criterion values were calculated by using EPA's Clean Water Act 304(a) guidance values (described in the total recoverable fraction) and then applying the conversion factors in 40 CFR Part 131, Stay of Federal Water Quality Criteria for Metals; Water Quality Standards; States' Compliance - Revision of Metals Criteria; Final Rules, 60 FR 22228 (May 4, 1995).

n. EPA is not promulgating human health criteria for these contaminants. However, permit authorities should address these contaminants in NPDES permit actions using the State's existing narrative criteria for toxics.

o. These criteria were promulgated for specific waters in California in the National Toxics Rule ("NTR"), codified at 40 CFR 131.36, 57 FR 60848-60923, December 22, 1992, as amended by 60 FR 22228, May 4, 1995. The specific waters to which the NTR criteria apply include: Waters of the State defined as bays or estuaries and waters of the State defined as inland, i.e., all surface waters of

the State not ocean waters. These waters specifically include the San Francisco Bay upstream to and including Suisun Bay and the Sacramento-San Joaquin Delta. Note: This rule does not supersede the NTR, as amended, for this criterion.

p. The CMC = 1/[(f1/CMC1)+ (f2/CMC2)] where f1 and f2 are the fractions of total selenium that are treated as selenite and selenate respectively, and f1 + f2 = 1. CMC1 and CMC2 are the CMCs for selenite and selenate, respectively, or 185.9 ug/l and 12.83 ug/l, respectively. This criterion is proposed in the total recoverable form. A criterion of 20 ug/l was promulgated for specific waters in California in the NTR, as amended, and was promulgated in the total recoverable form. The specific waters to which the NTR criterion applies include: Waters of the San Francisco Bay upstream to and including Suisun Bay and the Sacramento-San Joaquin Delta; and waters of Salt Slough, Mud Slough (north) and the San Joaquin River, Sack Dam to the mouth of the Merced River. Note: This rule does not supersede the NTR, as amended, for this criterion. The criterion in today's rule applies to additional waters of the United States in the State of California by this rulemaking. Note also: The State of California adopted and EPA approved a site specific criterion for the San Joaquin River, mouth of Merced to Vernalis; therefore, this proposed criterion does not apply to these waters.

q. This criterion is proposed in the total recoverable form. This criterion was promulgated for specific waters in California in the NTR, as amended, and was promulgated in the total recoverable form. The specific waters to which the NTR criterion applies include: Waters of the San Francisco Bay upstream to and including Suisun Bay and the Sacramento-San Joaquin Delta; and waters of Salt Slough, Mud Slough (north) and the San Joaquin River, Sack Dam to Vernalis. Note: This rule does not supersede the NTR, as amended, for this criterion. This criterion applies to additional waters of the United States in the State of California by this rulemaking. Note also: The State of California adopted and EPA approved a site-specific criterion for the Grassland Water District, San Luis National Wildlife Refuge, and the Los Banos State Wildlife Refuge; therefore, this proposed criterion does not apply to these waters.

r. These criteria were promulgated for specific waters in California in the NTR, as amended. The specific waters to which the NTR criteria apply include: Waters of the State defined as bays or estuaries including the San Francisco Bay upstream to and including Suisun Bay and the Sacramento-San Joaquin Delta. Note: This rule does not supersede the NTR, as amended, for these criteria.

s. These criteria were promulgated for specific waters in California in the NTR, as amended. The specific waters to which the NTR criteria apply include: Waters of the Sacramento-San Joaquin Delta and waters of the State defined as inland (i.e., all surface waters of the State not bays or estuaries or ocean) that include a MUN use designation. Note: This rule does not supersede the NTR, as amended, for these criteria.

t. These criteria were promulgated for specific waters in California in the NTR, as amended. The specific waters to which the NTR criteria apply include: Waters of the State defined as bays and estuaries including San Francisco Bay upstream to and including Suisun Bay and the Sacramento-San Joaquin Delta; and waters of the State defined as inland (i.e., all surface waters of the State not bays or estuaries or ocean) without a MUN use designation. Note: This rule does not supersede the NTR, as amended, for these criteria.

u. PCBs are a class of chemicals which include aroclors 1242, 1254, 1221, 1232, 1248, 1260, and 1016, CAS numbers 53469219, 11097691, 11104282, 11141165, 12672296, 11096825, and 12674112, respectively. The aquatic life criteria apply to this set of PCBs.

v. This criterion applies to total PCBs or congener or isomer analyses.

w. This criterion has been recalculated pursuant to the 1995 Updates: Water Quality Criteria Documents for the Protection of Aquatic Life in Ambient Water, Office of Water, EPA-820-B-96-001, September 1996. See also Great Lakes

Water Quality Initiative Criteria Documents for the Protection of Aquatic Life in Ambient Water, Office of Water, EPA-80-B-95-004, March 1995.

x. The State of California has adopted and EPA has approved site specific criteria for the Sacramento River (and tributaries) above Hamilton City; therefore, these proposed criteria do not apply to these waters.

General Notes:

1. This chart lists all of EPA's priority toxic pollutants whether or not criteria guidance are available. Blank spaces indicate the absence of criteria guidance. Because of variations in chemical nomenclature systems, this listing of toxic pollutants does not duplicate the listing in Appendix A of 40 CFR Part 423. EPA has added the Chemical Abstracts Service (CAS) registry numbers, which provide a unique identification for each chemical.

2. The following chemicals have organoleptic-based criteria recommendations that are not included on this chart (for reasons which are discussed in the preamble): zinc, 3-methyl-4-chlorophenol.

3. For purposes of this rulemaking, freshwater criteria and saltwater criteria apply as specified in 40 CFR 131.38(c)(3).

(2) Factors for Calculating Metals Criteria

$$CMC = WER \times (\text{Acute Conversion Factor}) \times (\exp\{m_A[\ln(\text{hardness})]+b_A\})$$
$$CCC = WER \times (\text{Chronic Conversion Factor}) \times (\exp\{m_C[\ln(\text{hardness})]+b_C\})$$

Final CMC and CCC values should be rounded to two significant figures.

Metal	Conversion Factor (CF) for freshwater acute criteria	CF for freshwater chronic criteria	CF for saltwater acute criteria	CF (a) for saltwater chronic criteria
Antimony	(d)	(d)	(d)	(d)
Arsenic	1.000	1.000	1.000	1.000
Beryllium	(d)	(d)	(d)	(d)
Cadmium (b)	0.944	0.909	0.994	0.994
Chromium (III)	0.316	0.860	(d)	(d)
Chromium (VI)	0.982	0.962	0.993	0.993
Copper	0.960	0.960	0.83	0.83
Lead (b)	0.791	0.791	0.951	0.951
Mercury	0.85	0.85	0.85	0.85
Nickel	0.998	0.997	0.990	0.990
Selenium	(c)	(c)	0.998	0.998
Silver	0.85	(d)	0.85	(d)
Thallium	(d)	(d)	(d)	(d)
Zinc	0.978	0.986	0.946	0.946

NOTE: The term "Conversion Factor" represents the recommended conversion factor for converting a metal criterion expressed as the total recoverable fraction in the water column to a criterion expressed as the dissolved fraction in the water column. See 'Office of Water Policy and Technical Guidance on Interpretation and Implementation of Aquatic Life Metals Criteria', October 1, 1993, by Martha G. Prothro, Acting Assistant Administrator for Water; and 40 CFR Part 131, Stay of Federal Water Quality Criteria for Metals; Water Quality Standards; Establishment of Numeric Criteria for Priority Toxic Pollutants; States' Compliance - Revision of Metals Criteria; Final Rules, 60 FR 22228, May 4, 1995.

(a) Conversion Factors for chronic marine criteria are not currently available. Conversion Factors for acute marine criteria have been used for both acute and chronic marine criteria.

(b) Conversion Factors for these pollutants are hardness dependent. CFs are based on a hardness of 100 mg/l as calcium carbonate ($CaCO_3$). Other hardness can be used; CFs should be recalculated using the following equations:

Cadmium: Acute: $CF = 1.136672 - [(\ln\{hardness\})(0.041838)]$
Chronic: $CF = 1.101672 - [(\ln\{hardness\})(0.041838)]$
Lead: Acute and Chronic: $CF = 1.46203 - [(\ln\{hardness\})(0.145712)]$

(c) Bioaccumulative compound and inappropriate to adjust to percent dissolved.

(d) EPA has not published an aquatic life criterion value.

Metal	m_A	b_A	m_C	b_C
Cadmium	1.128	-3.6867	0.7852	-2.715
Copper	0.9422	-1.700	0.8545	-1.702
Chromium (III)	0.8190	3.688	0.8190	1.561
Lead	1.273	-1.460	1.273	-4.705
Nickel	0.8460	2.255	0.8460	0.0584
Silver	1.72	-6.52	---	---
Zinc	0.8473	0.884	0.8473	0.884

NOTE: The term "exp" represents the base e exponential function.

(c) Applicability. (1) The criteria in paragraph (b) of this section apply to the State's designated uses cited in paragraph (d) of this section and apply concurrently with any criteria adopted by the State, except when State regulations contain criteria which are more stringent for a particular parameter and use, or except as provided in footnotes p, q, and x in paragraph (b) of this section.

(2) The criteria established in this section are subject to the State's general rules of applicability in the same way and to the same extent as are other Federally-adopted and State-adopted numeric toxics criteria when applied to the same use classifications including mixing zones, and low flow values below which numeric standards can be exceeded in flowing fresh waters.

(i) For all waters with mixing zone regulations or implementation procedures, the criteria apply at the appropriate locations within or at the boundary of the mixing zones; otherwise the criteria apply throughout the water body including at the point of discharge into the water body.

(ii) The State shall not use a low flow value below which numeric standards can be exceeded that is less stringent than the following for water suitable for the establishment of low flow return frequencies (i.e., streams and rivers):

Aquatic Life: Acute Criteria (CMC): 1 Q 10 or 1 B 3
Chronic Criteria (CCC): 7 Q 10 or 4 B 3

Human Health: Non-carcinogens: 30 Q 5
Carcinogens: Harmonic Mean Flow

Where: CMC (Criteria Maximum Concentration) is the water quality criteria to protect against acute effects in aquatic life and is the highest instream concentration of a priority toxic pollutant consisting of a short-term average not to be exceeded more than once every three years on the average;

CCC (Continuous Criteria Concentration) is the water quality criteria to protect against chronic effects in aquatic life and is the highest in stream concentration of a priority toxic pollutant consisting of a 4-day average not to be exceeded more than once

every three years on the average;

1 Q 10 is the lowest one day flow with an average recurrence frequency of once in 10 years determined hydrologically;

1 B 3 is biologically based and indicates an allowable exceedence of once every 3 years. It is determined by EPA's computerized method (DFLOW model);

7 Q 10 is the lowest average 7 consecutive day low flow with an average recurrence frequency of once in 10 years determined hydrologically;

4 B 3 is biologically based and indicates an allowable exceedence for 4 consecutive days once every 3 years. It is determined by EPA's computerized method (DFLOW model);

30 Q 5 is the lowest average 30 consecutive day flow with an average recurrence frequency of once in 5 years determined hydrologically; and the harmonic mean flow is a long term mean flow value calculated by dividing the number of daily flows analyzed by the sum of the reciprocals of those daily flows.

(iii) If the State does not have such a low flow value below which numeric standards do not apply, then the criteria included in paragraph (d) or this section herein apply at all flows.

(3) The aquatic life criteria in the matrix in paragraph (b) of this section apply as follows:

(i) For waters in which the salinity is equal to or less than 1 part per thousand 95% or more of the time, the applicable criteria are the freshwater criteria in Column B;

(ii) For waters in which the salinity is equal to or greater than 10 parts per thousand 95% or more of the time, the applicable criteria are the saltwater criteria in Column C except for selenium in the San Francisco Bay estuary where the applicable criteria are the freshwater criteria in Column B (refer to footnotes p and q in section (b)(1) above); and

(iii) For waters in which the salinity is between 1 and 10 parts per thousand as defined in paragraphs (c)(3)(I) and (ii) of this section, the applicable criteria are the more stringent of the freshwater or saltwater criteria. However, the Regional Administrator may approve the use of the alternative freshwater or saltwater criteria if scientifically defensible information and data demonstrate that on a site-specific basis the biology of the water body is dominated by freshwater aquatic life and that freshwater criteria are more appropriate; or conversely, the biology of the water body is dominated by saltwater aquatic life and that saltwater criteria are more appropriate.

(4) Application of metals criteria. (i) For purposes of calculating freshwater aquatic life criteria for metals from the equations in paragraph (b)(2) of this section, for waters with a hardness of 400 mg/l or less as calcium carbonate, the actual ambient hardness of the surface water shall be used in those

equations. For waters with a hardness of over 400 mg/l as calcium carbonate, a hardness of 400 mg/l as calcium carbonate shall be used with a default Water-Effect Ratio (WER) of 1, or the actual hardness of the ambient surface water shall be used with a WER. The same provisions apply for calculating the metals criteria for the comparisons provided for in paragraph (c)(3)(iii) of this section.

(ii) The hardness values used shall be consistent with the design discharge conditions established in paragraph (c)(2) of this section for flows and mixing zones.

(iii) The criteria for metals (compounds #1 - #13 in paragraph (b) of this section) are expressed as dissolved except where otherwise noted. For purposes of calculating aquatic life criteria for metals from the equations in footnote i in the criteria matrix in paragraph (b)(1) of this section and the equations in paragraph (b)(2) of this section, the water effect ratio is generally computed as a specific pollutant's acute or chronic toxicity value measured in water from the site covered by the standard, divided by the respective acute or chronic toxicity value in laboratory dilution water. To use a water effect ratio other than the default of 1, the WER must be determined as set forth in Interim Guidance on Determination and Use of Water Effect Ratios, U.S. EPA Office of Water, EPA-823-B-94-001, February 1994, or alternatively, other scientifically defensible methods adopted by the State as part of its water quality standards program and approved by EPA. For calculation of criteria using site-specific values for both the hardness and the water effect ratio, the hardness used in the equations in paragraph (b)(2) of this section must be determined as required in paragraph (c)(4)(ii) of this section. Water hardness must be calculated from the measured calcium and magnesium ions present, and the ratio of calcium to magnesium should be approximately the same in standard laboratory toxicity testing water as in the site water.

(d)(1) Except as specified in paragraph (d)(3), below, all waters assigned any aquatic life or human health use classifications in the Water Quality Control Plans for the various Basins of the State ("Basin Plans"), as amended, adopted by the California State Water Resources Control Board ("SWRCB"), except for ocean waters covered by the Water Quality Control Plan for Ocean Waters of California ("Ocean Plan") adopted by the SWRCB with resolution Number 90-27 on March 22, 1990, are subject to the criteria in paragraph (d)(2) of this section, without exception. These criteria apply to waters contained in the Basin Plans. More particularly, these criteria apply to waters in the Basin Plan chapters specifying water quality objectives (the State equivalent of federal water quality criteria) for the toxic pollutants identified in paragraph (d)(2) of this section. Although the State has adopted several use designations

for each of these waters, for purposes of this action, the specific standards to be applied in paragraph (d)(2) of this section are based on the presence in all waters of some aquatic life designation and the presence or absence of the MUN use designation (municipal and domestic supply). (See Basin Plans for more detailed use definitions.)

(2) The following criteria from the matrix in paragraph (b)(1) of this section apply to the water and use classifications defined in paragraph (d)(1) of the section and identified below:

Water and use classification	Applicable Criteria
All inland waters of the United States or enclosed bays and estuaries that are waters of the United States that include a MUN use designation	These waters are assigned the criteria in: Columns B1 and B2 - all pollutants Columns C1 and C2 - all pollutants Column D1 - all pollutants
All inland waters of the United States or enclosed bays and estuaries that are waters of the United States that do not include a MUN use designation	These waters are assigned the criteria in: Columns B1 and B2 - all pollutants Columns C1 and C2 - all pollutants Column D2 - all pollutants

(3) Nothing in this section is intended to supersede specific criteria, including specific criteria for the San Francisco Bay estuary, promulgated for California in the National Toxics Rule, 40 CFR 131.36, 57 FR 60848-60923, December 22, 1992, as amended by 60 FR 22228, May 4, 1995.

(4) The human health criteria shall be applied at the State-adopted 10 (-6) risk level.

(5) Nothing in this section applies to waters located in Indian Country.

(e) Schedules of Compliance: (1) It is presumed that new and existing point source dischargers will promptly comply with any new or more restrictive water quality-based effluent limitations ("WQBELs") based on the water quality criteria set forth in this section.

(2) When a permit issued on or after the effective date of this regulation to a new discharger contains a WQBEL based on water quality criteria set forth in the section, the permittee shall comply with such WQBEL upon the commencement of the discharge. A new discharger is defined as any building, structure, facility, or

installation from which there is or may be a "discharge of pollutants" (as defined in 40 CFR 122.2) to the State of California's inland surface waters or enclosed bays and estuaries, the construction of which commenced after the effective date of this regulation.

(3) Where an existing discharger reasonably believes that it will be infeasible to promptly comply with a new or more restrictive WQBEL based on the water quality criteria set forth in this section, the discharger may request approval from the permit issuing authority for a schedule of compliance.

(4) A compliance schedule shall require compliance with WQBELs based on water quality criteria set forth in this section as soon as possible, taking into account the dischargers technical ability to achieve compliance with such WQBEL.

(5) If the schedule of compliance exceeds one year from the date of permit issuance, reissuance or modification, the schedule shall set forth interim requirements and dates for their achievement. The dates of completion between each requirement may not exceed one year. If the time necessary for completion of any requirement is more than one year and is not readily divisible into stages for completion, the permit shall require, at a minimum, specified dates for annual submission of progress reports on the status of interim requirements.

(6) In no event shall the permit issuing authority approve a schedule of compliance for a point source discharge which exceeds five years from the date of permit issuance, reissuance, or modification, whichever is sooner. Where shorter schedules of compliance are prescribed or schedules of compliance are prohibited by law, those provisions shall govern.

(7) If a schedule of compliance exceeds the term of a permit, interim permit limits effective during the permit shall be included in the permit and addressed in the permit's fact sheet or statement of basis. The administrative record for the permit shall reflect final permit limits and final compliance dates. Final compliance dates for final permit limits, which do not occur during the term of the permit, must occur within five years from the date of issuance, reissuance or modification of the permit which initiates the compliance schedule. Where shorter schedules of compliance are prescribed or schedules of compliance are prohibited by law, those provisions shall govern.

(8) No compliance schedule established in accordance with paragraphs (e)(3)-(7) of this section shall allow more than ten years from the effective date of this rule to achieve compliance with any WQBEL based on the criteria set forth in this section.

CHARACTERIZATION OF BASELINE WATER QUALITY

CHAPTER 2

INTRODUCTION

To characterize the potential benefits associated with achieving EPA's proposed numeric criteria for priority pollutants, we begin by describing current water quality conditions in California. Information on the extent to which State waters currently meet the proposed criteria is incomplete. Water quality conditions in many State waters have not yet been fully assessed, and assessments of waters that have been evaluated often do not contain monitoring data that is extensive or detailed enough to determine whether the waterbody meets all of the proposed criteria. Nonetheless, there are numerous sources of information on current water quality conditions in California, many of which attempt to characterize the nature and extent of toxics pollution. We rely on these sources to describe current water quality conditions in California's inland waters, enclosed bays, and estuaries.

Our analysis indicates that toxic pollutants impair many of California's surface water resources.[1] Exhibit 2-1 summarizes the water quality assessment for the entire state.

- Toxic pollutants adversely affect large areas of surface water in California. Available data suggest that over 800,000 acres of bays, estuaries, lakes, and wetlands are affected by toxics, as are over 3,700 miles of rivers. Most notably, over two-thirds of the assessed area of both bays and saline lakes are thought to be affected by toxics.

[1] We define "impaired" waters as those that are rated by the State of California as medium or poor water quality for at least one toxic water quality pollutant or groups of pollutants. See text below for a more detailed discussion.

Exhibit 2-1

SUMMARY OF CALIFORNIA REGIONAL WATER QUALITY ASSESSMENTS

Region	Areal Extent of Toxics Impairment	Pollutants of Concern	Primary Pollutant Sources	Key Waterbodies Affected	Natural Resources and Beneficial Uses Affected
Region 1: North Coast Region	55% of bays (16,500 acres); minor impairment of other waterbodies	Metals, pesticides	Mix of point sources (municipal and industrial effluent) and nonpoint sources (agriculture and urban runoff)	Arcata Bay, Humboldt Bay	Recreation, municipal supply, wildlife habitat (e.g., salmon); fish spawning and/or migration; rare and endangered species
Region 2: San Francisco Bay	Large areas impaired by toxics, including 70% of bays (200,000 acres); 60% of wetlands (57,000 acres); 39% of rivers (244 miles)	Metals, trace elements, priority organics	Urban runoff and other nonpoint sources affect largest areas; some impairment from municipal and industrial point sources	San Francisco Bay (Lower, Central, South), Suisun Marsh	Recreation, commercial fishing; wildlife habitat, fish migration and/or spawning; rare and endangered species; elevated concentrations of toxics in shellfish, fish, and waterfowl; fish consumption advisories for several waterbodies, including San Francisco Bay, Lake Herman, Guadalupe Reservoir, and others; waterfowl consumption advisory.
Region 3: Central Coast Region	47% of lakes (11,700 acres); 36% of estuaries (1,700 acres); minor impairment of rivers and bays	Metals, pesticides	Agriculture, mining, unspecified nonpoint sources	Morro Bay, Carpinteria Marsh, Elkhorn Slough	Recreation, wildlife habitat; fish consumption advisory for Nacimiento River; fish migration and/or spawning; rare and endangered species
Region 4: Los Angeles Basin	Over 90% of bays and estuaries impaired (16,000 acres); minor impairment of rivers and lakes	Pesticides, priority organics, trace elements	Mix of point sources (municipal treatment, "other" point sources) and nonpoint sources (agriculture, hydrological modification, and urban runoff)	Mugu Lagoon San Gabriel River (lower), Los Angeles River (upper)	Recreation, commercial shellfishing, navigation, wildlife habitat; fish migration and/or spawning; rare and endangered species; fish consumption advisories for Lake Nacimiento and Los Angeles Harbor
Region 5: Central Valley Region	Large areas impaired by toxics, including 100% of estuaries (48,000 acres); 23% of lakes (120,000 acres); 21% of rivers (1,200 miles)	Metals, trace elements	Agriculture, mining; smaller areas affected by municipal treatment, urban runoff, storm sewers, and other nonpoint sources	Delta Waterways, Clear Lake, American River, Feather River, Sacramento River, Grasslands Marshes, Shasta Lake	Municipal supply, agriculture, recreation, wildlife habitat; fish migration and/or spawning; rare and endangered species; fish consumption advisories for Clear Lake, Lake Berryessa, and Grasslands Area; waterfowl consumption advisory for Grasslands Area
Region 6: Lahontan Region	34% of saline lakes (66,000 acres); 19% of lakes (36,000 acres; 13% of rivers (372 miles)	Metals, trace elements, priority organics	Naturally occurring levels of metals and trace elements; lesser areas affected by agriculture, land development, and mining	Eagle Lake, Owens River, Truckee River, Honey Lake	Recreation, municipal supply (exported); fish migration and/or spawning; rare and endangered species
Region 7: Colorado River Basin	60% of rivers (1,400 miles) impaired; 220,000 acres of saline lake (Salton Sea)	Pesticides, trace elements	Agriculture	Salton Sea	Recreation, wildlife habitat; rare and endangered species; fish consumption advisory for Salton Sea

Exhibit 2-1

SUMMARY OF CALIFORNIA REGIONAL WATER QUALITY ASSESSMENTS

Region	Areal Extent of Toxics Impairment	Pollutants of Concern	Primary Pollutant Sources	Key Waterbodies Affected	Natural Resources and Beneficial Uses Affected
Region 8: Santa Ana River Basin	Over 90% of bays and estuaries impaired (4,000 acres); 27% of lakes (4,000 acres)	Metals, pesticides	Primarily nonpoint sources including agriculture, urban runoff, and land development	Upper Newport Bay	Recreation, municipal supply, wildlife habitat, fish spawning and/or migration
Region 9: San Diego Basin	14% of estuaries; minor impairment of other waterbodies	Metals, pesticides, priority organics, trace elements	Estuaries affected by land disposal; other waterbodies affected by diverse mix of point and nonpoint sources	San Diego Bay, Tijuana River Estuary	Recreation, commercial fishing and shellfishing, wildlife habitat, fish spawning and/or migration, rare and endangered species

Source: EPA analysis of 1994 California Water Quality Assessment data base; State of California data on fish and waterfowl consumption advisories. Some key waterbodies impaired by toxics may have changed since the 1994 analysis, but more recent data were not used in the preparation of this report due to time constraints.

- Both point and nonpoint sources play a role in contributing to toxic pollution. Agriculture, primarily agricultural drainage, is the most frequently cited pollution source that impairs rivers and is also frequently cited as a contributor to the impairment of lakes and reservoirs. Urban runoff and "other" nonpoint sources (e.g., deposition, spills) are most frequently cited as factors contributing to water quality problems in toxics-impaired bays. Mining is the most frequently cited point source, particularly for lakes and reservoirs, while toxics discharged by municipal wastewater treatment plants contribute to the impairment of a variety of waterbody types, particularly estuaries and wetlands.

- Inorganic pollutants such as metals and trace elements are the most significant categories of toxic pollutants affecting waters statewide. Pesticides are also associated with large areas of impairment.

- Based on the areal extent of contamination and the uses of affected waterbodies, San Francisco Bay and the Central Valley appear to be the areas most influenced by toxic contamination. In addition, toxics adversely affect a high percentage of river and saline lake area in the Colorado River Basin. While these areas constitute those most extensively affected by toxics, waters in all regions show some degree of toxics impairment.

- Review of regional basin reports suggests that numerous affected waterbodies currently or formerly supported recreational activity, and several are used for commercial fishing or municipal water supplies. In addition, nearly all of the affected waters serve as wildlife habitat, including habitat for threatened and endangered species.

The following discussion summarizes available information on the nature and extent of toxic pollution in waters subject to the proposed water quality criteria. It begins by describing the data and analytic methods employed to characterize current water quality. It then presents the results of the analysis, describing the share of State waters impaired by toxics, the specific pollutants that contribute to impairment of water quality, and the sources of these pollutants. The discussion also summarizes a more detailed assessment of water quality conditions in each of the State's nine Water Quality Control Board regions. Appendix A presents the full detailed, regional assessment.

DATA AND METHODOLOGY

Our primary source of information on surface water quality in California is the State's Water Quality Assessment (WQA) database, developed and maintained by the State Water Resources Control Board (SWRCB). The WQA is a compilation of data from the State's nine regional Water Quality Control Boards and is organized by region and by waterbody type. It contains a range of information on surface water pollution, including the pollutants that adversely affect water quality in bodies of water that have been evaluated, the sources of pollution, the beneficial uses impaired, and an overall rating of water quality. The State relies on the WQA to develop the biennial water quality report required by §305(b) of the Clean Water Act. The WQA was last updated in 1994.[2]

The WQA is comprised of three major files: FACTSHT, SITEDATA, and POLLUTANT. We relied on two of these files, POLLUTANT and SITEDATA, to characterize the extent to which toxic pollutants adversely affect California's surface water resources. Both POLLUTANT and SITEDATA report State evaluations of individual waterbodies or waterbody segments, each stressing different aspects of the assessment. POLLUTANT presents information on the region in which the waterbody is located, the size (acres or miles) of the waterbody or waterbody segment, the types of pollutants affecting the waterbody, and the sources of those pollutants. SITEDATA classifies waterbodies by type, identifies the beneficial uses of each waterbody, and indicates the number of stream miles or acres to which the State has assigned water quality ratings of "good," "medium," "poor," or "unknown." As described below, we rely on information from both files to identify California waters adversely affected by the toxic pollutants of interest.

Relevant Pollutants

The WQA includes data on a range of pollutants, including conventional pollutants and non-conventional pollutants that are not addressed by the proposed rule. To identify waters impaired by the pollutants of interest (toxic pollutants as defined by section 307(a) of the CWA), we cross-referenced the pollutants cited in the WQA with those for which EPA proposes to establish criteria. Exhibit 2-2 presents the resulting list of pollutants, along with the pollutant group to which they belong (e.g., metals), as identified in the WQA. In analyzing the WQA to identify waters impaired by the toxic pollutants of interest, we employ the subset of pollutants and pollutant groups listed in the exhibit.

---

[2] *Water Quality Assessment*; State Water Resources Control Board, California Environmental Protection Agency, December 1994, p. i.

Exhibit 2-2

WQA POLLUTANTS INCLUDED IN THE BASELINE ASSESSMENT OF CRITERIA POLLUTANT IMPACTS

Specific	Group
Cadmium	Metal
Chromium	Metal
Copper	Metal
Lead	Metal
Mercury	Metal
Nickel	Metal
Silver	Metal
Unspecified. Metals	Metal
Zinc	Metal
Arsenic	Trace Element
Beryllium	Trace Element
Selenium	Trace Element
Unspecified Trace Element	Trace Element
Unspecified Toxic	Misc. Toxic
2,4-D	Pesticide
Aldrin	Pesticide
Alpha-HCH	Pesticide
Beta-HCH	Pesticide
Chlordane	Pesticide
DDT	Pesticide
Dieldrin	Pesticide
Endosulfan	Pesticide
Endosulfan I	Pesticide
Endrin	Pesticide
Group A	Pesticide
HCB	Pesticide
HCH (Total)	Pesticide
Heptachlor	Pesticide
Heptachlor E	Pesticide
Herbicide	Pesticide
Lindane	Pesticide
PCP	Pesticide
Toxaphene	Pesticide
Unspecified Pesticide	Pesticide
PAH	Priority Organic
PCB's	Priority Organic
TCE	Priority Organic
Unspecified. Priority Organic	Priority Organic

Exhibit 2-2 includes a number of pesticides listed by brand name, as they appear in the WQA. In determining whether to include such pesticides in our analysis, we used the Registry of Toxic Effects of Chemical Substances to identify their ingredients. Brand name pesticides are included in the analysis only if their ingredients include compounds addressed by the proposed rule.

Exhibit 2-2 also includes several broad categories of pollutants listed in the WQA (e.g., Group A pesticides, or unspecified metals, toxics, pesticides, priority organics, or trace elements). We include these categories in our analysis because they are likely to encompass one or more of the specific pollutants addressed by the proposed rule. Similarly, we include in the analysis waters that the WQA indicates are impaired by a relevant pollutant group -- i.e., metals, pesticides, priority organics, or trace elements -- when no specific pollutant is listed. Since these categories or groups may include pollutants other than those addressed by the proposed rule, this approach may overstate the impact of the pollutants of interest; available data are insufficient to estimate the magnitude of this potential effect. The approach is preferable, however, to excluding these categories or groups from the analysis, since to do so would clearly understate current impacts.

Finally, there are several specific constituents for certain waterbodies in California that are not included in the proposed rulemaking because EPA promulgated criteria for these pollutants in a prior rulemaking (December 22, 1992 National Toxics Rule [40 CFR Part 131.36]). A detailed summary of these constituents and waterbodies is presented in Chapter 1 along with a table of the proposed water quality criteria. In describing the baseline conditions for waters in California, we were not able to adjust the summary of water quality assessments to reflect this prior criteria promulgation because the WQA data base did not include constituent-specific statistics. For example, the National Toxics rule promulgated an aquatic life criterion for selenium for San Francisco Bay. However, selenium is not specifically listed in the WQA, and is included only under the "trace element" grouping. Consequently, we were not able to adjust downward ("net out") the San Francisco Bay acreage affected by selenium in our summary tables. We do, however, attempt to adjust for earlier promulgations in the assessment of ecological, human health, and economic benefits, as described in later chapters.

Identifying Impaired Waters

To identify the extent to which California waters are adversely affected by the toxic pollutants of interest, we employ data from both the SITEDATA and POLLUTANT files. The definition of "impaired" that we employ is based on the water quality ratings assigned by the WQA. As noted above, SITEDATA classifies the quality of assessed waters as good, medium, poor, or unknown. The State defines the first three ratings as follows:

- Good quality waters support and enhance designated beneficial uses.
- Medium quality waters support designated beneficial uses with occasional degradation and include waters suspected to be "poor" where available data are inadequate to allow a definitive conclusion.
- Poor waters are those that cannot reasonably be expected to support designated beneficial uses.[3]

For the purposes of this analysis, we define impaired waters as those rated "medium" or "poor." We focus solely on the State's inland waters, enclosed bays, and estuaries, excluding from the analysis the State's ocean waters, which are unaffected by the proposed rule.

To arrive at an estimate of the waterbody area impaired specifically by toxics (rather than conventional pollutants), we first look at the POLLUTANT table. Since this table contains pollutant-specific information for each waterbody, we link this table to the list of toxics regulated under the proposed rule. We delete any waterbody that does not possess at least one of the toxics listed in Exhibit 2-2 from the POLLUTANT data table.

Using the abridged POLLUTANT data table, which now contains only those waterbodies having toxics regulated under the proposed rule, we identify the impaired waterbody area by looking at the table's "Segment Size" field. This area is preferable to the area listed in SITEDATA because it is specifically linked with the toxic pollutant(s), whereas the SITEDATA area cannot be linked to specific pollutants.

In some cases, however, the POLLUTANT file is incomplete; indicating that a water segment is affected by toxics, but failing to note the areal extent of toxics impairment (i.e., the "Segment Size" field is either blank or contains a zero value). In these cases, we rely on information in the SITEDATA table to identify the areal extent of potential toxics impacts. Since the SITEDATA figures indicate the areal extent of impairment without reference to the pollutant(s) that cause(s) the impairment, this approach may overstate the extent to which the pollutants of concern adversely affect State waters. The extent of any such overstatement, however, is unknown.[4]

---

[3] *Water Quality Assessment*; State Water Resources Control Board, California Environmental Protection Agency, December 1994.

[4] For a more detailed description of the methodology used in analyzing the WQA data, see: memorandum prepared for Christine Ruf, OPPE, prepared by Matt Schwartz and Bob Black, Industrial Economics, Incorporated, "Analysis of the 1994 California Water Quality Assessment Database," May 21, 1997.

Limitations of the Analysis

According to water quality experts from U.S. EPA and the State of California, some of the assumptions used in the analysis may have created a bias towards overestimating the extent of toxics contamination when this information was extrapolated to all waters in the State. These include assuming that the percentage of toxics impairment found in assessed waters was the same as the percentage of toxic impairment of waters throughout the State; that waters rated as medium impaired waters (those which partially support their uses) were counted together with those rated as poor impaired waters (those which do not support their uses); and that waters listed as impaired in one data base, and associated with toxics in a second data base, were considered waters impaired by toxics.

Although the consensus of the U.S. EPA and State experts was that the above assumptions may have created a bias toward overestimating toxics contamination Statewide, they also stated that certain other assumptions used in the analysis may *underestimate* the extent of toxics contamination. For example, the assumption that the type and scope of all toxics of concern in all State waters appear in the WQA data base may underestimate the extent of toxics impairment because of the infrequency of ambient monitoring throughout the State, or because of the difficulty of detecting the ambient concentrations of certain toxic pollutants when their water quality criteria fall below the minimum detection limit. Consequently, because of all of the uncertainties associated with the WQA data base, State of California and U.S. EPA experts advised against an attempt to quantitatively estimate the magnitude of the bias in either direction.

In addition to the limitations noted above, it is important to note that the waters we identify as impaired by the pollutants of interest may also be impaired by other pollutants; bringing these waters into compliance with the proposed criteria will not necessarily ensure compliance with all applicable water quality standards or ensure full support of all designated uses. Moreover, the WQA data and water quality ratings are based largely on the subjective evaluation of State experts, rather than extensive ambient water quality monitoring. The subjective nature of this information contributes to further uncertainty in the characterization of baseline water quality.

STATEWIDE ASSESSMENT OF TOXIC WATER POLLUTION

The data and analysis described above provide a general profile of the degree to which the toxic pollutants addressed by EPA's proposed criteria adversely affect water quality in California's inland waters, enclosed bays, and estuaries. The following discussion outlines the results of the analysis, including:

- the areal extent of toxic contamination;
- the primary sources of toxic contaminants; and
- the principal categories of toxic pollutants that impair surface waters.

Areal Extent of Contamination

Exhibit 2-3 summarizes the estimated extent of toxic contamination in California waters, based on analysis of the WQA data. The analysis indicates that the pollutants of interest impair over 800,000 acres of bays, estuaries, lakes, and wetlands, and over 3,700 miles of the State's rivers and streams.

Exhibit 2-3

TOXICS-IMPAIRED WATERS AS A PERCENTAGE OF ASSESSED WATERS

Waterbody Type	Area Impaired	Area Assessed	Percent of Assessed Area Impaired by Toxics
Inland Bays	229,774 acres	348,223 acres	66%
Estuaries	55,738 acres	119,683 acres	47%
Lakes & Reservoirs	175,552 acres	910,795 acres	19%
Rivers & Streams	3,737 miles	19,994 miles	19%
Saline Lakes	286,182 acres	416,416 acres	69%
Wetlands	66,680 acres	244,050 acres	27%

Source: EPA analysis of 1994 State of California WQA data.

To place these estimates in context, Exhibit 2-3 compares the figures given above to the share of surface water resources for which the WQA provides water quality assessments. As the exhibit indicates, relatively high percentages of assessed waters are impaired by toxics. In particular, approximately two-thirds of assessed bay and saline lake areas suffer toxics impairment.[5] Forty-seven percent of the estuarine waters that the State has evaluated are impaired by toxics, as are 27 percent of assessed wetlands. In addition, approximately 19 percent of lake and reservoir acreage and 19 percent of assessed stream and river miles are toxics-impaired.

[5] For some categories, the figures reported in Exhibit 2-3 are driven by conditions in a single large waterbody that accounts for most of the category's total assessed area. For example, most of the saline lake acreage impaired by toxics is attributable to the Salton Sea in southeast California, where 286,000 acres are affected.

Whether these figures are representative of conditions in unassessed waters is unknown. Although the WQA provides water quality assessments for only nine percent of California's total stream and river miles, and approximately 50 percent of wetlands, about 77 percent of State total lake and reservoir acreage has been assessed. Further, water quality analysts in EPA believe that nearly all bays/estuaries and saline lakes in the State have been well characterized, monitored, or otherwise evaluated for toxic contamination. As discussed earlier, based on recommendations from EPA and State of California water quality experts, we have not attempted to systematically adjust upwards or downwards the estimates given in Exhibit 2-3 to characterize the degree of impairment of all California waters.

Categories of Toxic Pollutants

Exhibit 2-4 summarizes the frequency with which the WQA cites major categories of toxic pollutants as contributors to water quality impairment. For each waterbody type, the exhibit indicates the total area impaired by each pollutant category and the percentage of the total impaired area with which the pollutant group is associated. Because a waterbody can be affected by more than one pollutant, the percentages do not add to 100.

Exhibit 2-4 suggests that inorganic pollutants such as metals and trace elements are the most common causes of water quality impairment by toxic pollutants statewide. The exhibit indicates that with the exception of saline lakes, metals are a major cause of impairment for all waterbody types. Metals contribute to the impairment of more than 90 percent of bay and estuarine areas adversely affected by toxics, are cited as a factor in 87 percent of toxics-impaired lakes, reservoirs, and wetlands, and contribute to impairment of 37 percent of the river and stream miles identified as toxics-impaired. Trace elements, particularly selenium, also affect a large share of impaired waters.[6] This is especially true for saline lakes, where all impaired waters are influenced by trace elements. Trace elements also contribute greatly to impairment of bays, rivers, and streams.

[6] An aquatic life criterion for selenium is already in effect for certain waterbodies in the state, such as the Bay-Delta. However, current selenium criteria may not be stringent enough to adequately protect some aquatic-dependent wildlife species.

Exhibit 2-4

EXTENT OF IMPAIRMENT BY POLLUTANT TYPE

	Total Area Impaired	Metals	Share of Total Toxics-Impaired Area	Pesticides	Share of Total Toxics-Impaired Area	Priority Organics	Share of Total Toxics-Impaired Area	Trace Elements	Share of Total Toxics-Impaired Area	Toxics	Share of Total Toxics-Impaired Area
Bays (acres)	229,774	218,334	95%	135,385	59%	13,110	6%	118,501	52%	67,874	30%
Estuaries (acres)	55,738	51,223	92%	52,480	94%	362	1%	2,749	5%	48,294	87%
Lakes and Reservoirs (acres)	175,552	152,563	87%	507	0%	50	0%	28,527	16%	6,441	4%
Rivers and Streams (miles)	3,737	1,344	36%	2,392	64%	61	2%	2,049	55%	762	20%
Saline Lakes (acres)	286,182	0	0%	0	0%	0	0%	286,182	100%	0	0%
Wetlands (acres)	66,680	57,870	87%	588	1%	160	0%	8,274	12%	400	1%

Source: EPA analysis of California WQA data.

Although less commonly cited than metals or trace elements, pesticides also contribute significantly to toxic pollution in California waters. As Exhibit 2-4 shows, the WQA lists pesticides as a concern for 94 percent of toxics-impaired estuarine waters. In addition, pesticides are identified as the leading cause of impairment in toxics-impaired rivers and streams (64 percent of impaired stream miles), and contribute to the pollution of 59 percent of the toxics-impaired waters in inland bays.

In comparison to the other pollutant categories, priority organic pollutants play a relatively minor role. The WQA lists priority organics as a causal factor for only six percent of toxics-impaired bay waters, two percent of toxics-impaired river and stream miles, and less than one percent of other toxics-impaired waters.

Toxic Pollutant Sources

The WQA identifies 11 pollution source categories, including agriculture, hydrological/habitat modification, industrial point sources, land development, land disposal, mining, municipal point sources, storm sewers, "other" point sources, urban runoff, and "other" nonpoint sources (air deposition, cross-border pollution, spills, and natural sources). Each of these sources contributes to water quality problems in State waters that are impaired by toxic pollutants. Exhibit 2-5 summarizes the available data on these sources, indicating, for each waterbody type, the total area of toxic impairment for which the WQA lists the source. The exhibit also indicates the percentage of the total toxics-impaired area that is associated with each source. Because a waterbody can be affected by more than one source, the percentages do not add to 100.

The WQA data indicate that both point and nonpoint sources contribute significantly to toxic pollution, although the importance of different sources varies considerably across waterbody categories. For example, "other" nonpoint sources are cited most frequently as contributors to pollution in toxics-impaired bays, followed by urban runoff and municipal point source discharges.[7] In contrast, the WQA identifies a wide range of sources -- including agriculture, hydrological/habitat modification, mining, municipal point sources, urban runoff, and "other" point and nonpoint sources -- as frequent contributors to the pollution of toxics-impaired estuaries. Mining, "other" nonpoint sources, and land development are the leading sources of pollution in toxics-impaired lakes and reservoirs. For toxics-impaired rivers and streams, agriculture is the most frequently listed pollution source, followed by "other" nonpoint sources, mining, and urban runoff.

---

[7] The WQA frequently lacks information on pollution sources for enclosed bays. This accounts in part for the relatively low percentages of toxics-impaired bay areas that are associated with specific sources.

Exhibit 2-5

MAJOR SOURCES OF TOXIC POLLUTANTS IN CALIFORNIA WATERBODIES

	Bays (acres)	Share of Total Toxics-Impaired Area	Estuaries (acres)	Share of Total Toxics-Impaired Area	Lakes & Reservoirs (acres)	Share of Total Toxics-Impaired Area	Rivers & Streams (miles)	Share of Total Toxics-Impaired Area	Saline Lakes (acres)	Share of Total Toxics-Impaired Area	Wetlands (acres)	Share of Total Toxics-Impaired Area
Agriculture	17,860	8%	51,883	93%	2,410	1%	2,260	60%	286,182	100%	9,211	14%
Hydro/Habitat Modification	2,100	<1%	48,150	86%	0	0%	40	1%	0	0%	0	0%
Industrial	16,805	7%	238	<1%	295	<1%	273	7%	0	0%	0	0%
Land Development	0	0%	1,182	2%	26,500	15%	106	3%	10,855	4%	500	1%
Land Disposal	0	0%	1,261	2%	0	0%	19	1%	0	0%	400	1%
Mining	474	<1%	48,000	86%	106,748	61%	930	25%	0	0%	2	0%
Municipal	27,201	12%	48,003	86%	0	0%	276	7%	0	0%	57,000	85%
Other Nonpoint Sources	83,149	36%	52,731	95%	64,350	37%	987	26%	230,855	81%	58,204	87%
Other Point Sources	12,910	6%	0	0%	0	0%	4	<1%	0	0%	0	0%
Storm Sewers	165	<1%	1,457	3%	0	0%	185	5%	0	0%	235	<1%
Urban Runoff	44,152	19%	50,880	91%	7,995	5%	537	14%	0	0%	58,203	87%

Source: EPA analysis of California 1994 WQA data.

In contrast to the data on other categories, the source data on toxics-impaired saline lakes and wetlands primarily reflect conditions in each category's largest waterbody. The saline lake category is dominated by the Salton Sea (220,000 acres), which is affected by agriculture in the Imperial Valley as well as by other nonpoint sources. Likewise, the wetlands category is dominated by the San Francisco Bay region's Suisun Marsh (48,000 acres), which is affected by municipal point source discharges as well as by urban runoff and other nonpoint sources.

REGIONAL ASSESSMENT OF TOXICS IMPAIRMENT

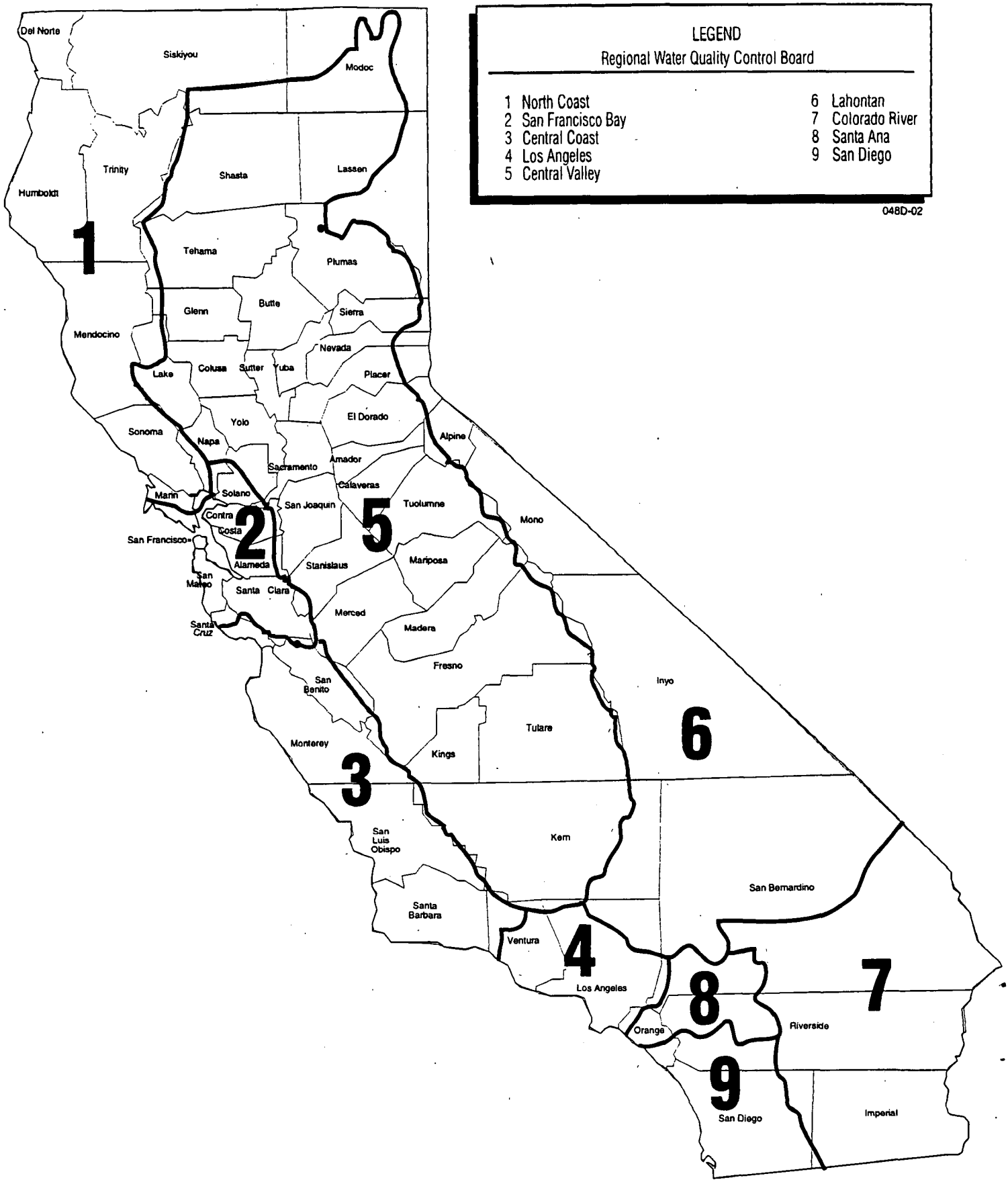
To provide a more thorough assessment of toxic pollution in California waters, we have developed detailed profiles of water quality conditions in each of the State's nine water quality regions (see Figure 2-1 for the regions' locations). Appendix A presents these regional profiles, including an overview of regional hydrology, a discussion of the nature and extent of toxic pollution in each region, and a description of toxic pollutant impacts on major bays, estuaries, lakes, rivers and wetlands. The following discussion identifies the sources consulted in developing these regional assessments, then briefly summarizes the analysis, focusing on the regions and major waterbodies most affected by toxic pollutants.

Information Sources

In addition to analysis of the WQA, the regional assessment relies on a number of additional sources to describe current water quality conditions in California, including regional basin reports, the State's CWA § 305(b) and § 303(d) reports, and the California Bay Protection and Toxic Cleanup Program. These sources are described briefly below.

- **Basin Reports:** In accordance with § 303(c) of the Clean Water Act, California's nine Water Quality Control Boards each periodically issue basin reports documenting water quality objectives for each region. The basin reports provide information on regional hydrology and describe the beneficial uses of the region's waterbodies. They also provide information on regional water quality issues.

Figure 2-1


LEGEND
Regional Water Quality Control Board
1 North Coast
2 San Francisco Bay
3 Central Coast
4 Los Angeles
5 Central Valley
6 Lahontan
7 Colorado River
8 Santa Ana
9 San Diego
048D-02
Del Norte
Siskiyou
Modoc
Trinity
Shasta
Lassen
Humboldt
Tehama
Plumas
Glenn
Butte
Sierra
Mendocino
Nevada
Lake
Colusa
Sutter
Yuba
Placer
Yolo
El Dorado
Sonoma
Napa
Alpine
Sacramento
Amador
Calaveras
Marin
Solano
San Joaquin
Tuolumne
Contra Costa
Mono
San Francisco
Alameda
Stanislaus
Mariposa
San Mateo
Santa Clara
Merced
Santa Cruz
Madera
Fresno
San Benito
Inyo
Tulare
Monterey
Kings
Kern
San Luis Obispo
San Bernardino
Santa Barbara
Ventura
Los Angeles
Orange
Riverside
San Diego
Imperial
1
2
3
4
5
6
7
8
9

- **California §305(b) Report:** As required by CWA §305(b), California's biennial Report on Water Quality summarizes water quality conditions throughout the State. The report also provides anecdotal information on waterbodies in which toxic pollutants are a major concern, and highlights selected efforts to improve toxic pollution control.[8]

- **California §303(d) Report:** In accordance with CWA §303(d), the California Report on Impaired Surface Waters lists waters that do not support designated beneficial uses or meet water quality objectives. The report also indicates regional priorities for future efforts to improve water quality, ranking each impaired waterbody on a scale of 1 (highest) to 5 (lowest) based on: (1) the degree of impairment; and (2) the intrinsic value of the waterbody as a function of beneficial uses potentially associated with the waters.[9]

- **California's Bay Protection and Toxic Cleanup Program** (BPTCP) is a state-run effort to identify enclosed bays and estuaries most affected by toxic pollution and provide for their cleanup. This effort lists toxic "hot spots" and "potential hot spots". Hot spots are defined as areas exhibiting significant toxicity, high levels of bioaccumulation, and impairment of ecologic beneficial uses, while potential hot spots display elevated toxic concentrations in water or sediment, but lack sufficient data to designate as a known hot spot.[10]

Summary of Findings

Exhibit 2-1 (presented above) summarizes the findings of the State's regional water quality assessment. The exhibit provides the following information for each region:

- **Areal Extent of Toxics Impairment**: Identifies, by waterbody type, the percent of assessed area adversely affected by toxics, as indicated by analysis of WQA data.

---

[8] *Draft: California 305(b) Report on Water Quality*; State Water Resources Control Board, October 1994.

[9] In instances where regional staff could not agree on a waterbody ranking, no ranking is provided.

[10] *Bay Protection and Toxic Cleanup Program: Staff Report*, State Water Resources Control Board, State of California, November, 1993, p. 8.

- **Primary Sources**: Identifies the major sources of toxic pollutants in the region, as indicated by analysis of WQA data.

- **Key Waterbodies Impaired**: Identifies significant waterbodies affected by toxics, based on a cross-tabulation of WQA data with California's § 303(d) list. The waterbodies listed are those rated highest on the § 303(d) priorities list (i.e., those assigned a priority rating of 1 or 2).

- **Natural Resources and Beneficial Uses**: Identifies the ecological services and human uses associated with toxics-impaired waters. This information is based on the beneficial use tables included in the regional basin plans, supplemented with information from the WQA database.[11]

The regional assessment suggests that impairment of water quality by toxics is particularly significant in Region 2 (San Francisco Bay). According to the analysis of WQA data, San Francisco Bay alone accounts for approximately 85 percent of the total inland bay area affected by toxics. In addition, the WQA analysis indicates that approximately 60 percent of assessed wetlands in Region 2 -- a sizeable portion of the State total -- is affected by toxics, as is a significant share of the Region's rivers.[12] The WQA data on the sources of toxic pollutants in Region 2 are limited; however, the available data suggest that urban runoff and nonpoint sources are the principal toxics sources. Point sources are less prominent, with municipal treatment plants affecting the Suisun Marsh wetlands and mining contributing to impairment of some lakes and rivers. Other information sources support the WQA analysis. For example, research on San Francisco Bay compiled by EPA state and local agencies suggests that non-urban runoff is a major source of several toxics, including arsenic, cadmium, chromium, copper, lead, mercury, and zinc. Urban runoff contributes significant shares of lead and PCBs. Trace element loadings can be traced to irrigation return flows and other nonpoint sources in the Central Valley, transported to San Francisco Bay via the San Joaquin River.[13]

---

[11] The beneficial uses drawn from the basin reports are based on the best judgment of regional Water Quality Control Board staff. In most cases, the beneficial use is ongoing. Available data do not clearly indicate whether certain uses have been precluded by toxic pollution.

[12] Suisun Marsh accounts for all of the impaired wetland acreage.

[13] *State of the Estuary: San Francisco Estuary Project*, U.S. EPA and the Association of Bay Area Governments, June 1992, p. 172.

Toxics also affect a high percentage of assessed waters in the State's largest region, Region 5 (Central Valley). All of the estuarine waters assessed in the Region (48,000 acres) are adversely affected by toxics, as are approximately 23 percent of assessed lakes (120,000 acres) and 21 percent of assessed rivers (1,200 miles).[14] Agriculture and mining are the most significant sources of toxic pollutants in the Central Valley. The WQA data suggest that agriculture affects large portions of estuaries, rivers, and wetlands, while mining discharges affect estuaries, lakes, and rivers. Unspecified nonpoint sources, municipal wastewater treatment plants, storm sewers, and urban runoff also add to toxic impairment.

California's § 303(d) list indicates that many of the Central Valley waterbodies affected by toxics are high priorities for State action because of the degree of pollution and/or the beneficial uses associated with the waterbody. These include the Delta Waterways, Clear Lake, the lower sections of the American and Feather Rivers, and sections of the Sacramento River. Metals, pesticides, and unspecified toxics combine to affect these waterbodies. Shasta Lake and the Grasslands Marshes, which are also high priority waters, are affected by metals and trace elements, respectively.

A number of other State water quality regions also suffer high degrees of toxics pollution. For example, toxic pollutants associated with agricultural activity in Region 7 -- the Colorado River Basin in southeast California -- impair a significant percentage of the Region's river and saline lake areas. Trace element contamination in the Salton Sea accounts for the majority of impaired saline lake acreage in California. Similarly, over 1,400 river miles in Region 7 are affected by pesticides and trace elements from agricultural activity; this accounts for about 40 percent of all impaired river miles statewide.

The beneficial uses associated with toxics-impaired waterbodies are diverse and suggest that toxic pollution affects critical areas. As shown in Exhibit 2-1, every region contains toxics-impaired waters that are intended to support both contact (e.g., swimming, fishing) and non-contact (e.g., boating) recreational activities. As just one indicator of impairment, toxics pollution has led to fish consumption advisories in several areas. Likewise, all the regions include toxics-impaired waters that function as wildlife habitat. In many cases, the affected area supports an endangered species or has been afforded "wild and scenic" status. As one example, both the Klamath (Region 1) and Sacramento (Region 5) Rivers support endangered salmon species.

---

[14] The Delta Waterways account for all of the impaired estuarine area.

A variety of other beneficial uses are associated with California's toxics-impaired waters. For example, commercial fishing and shellfishing are common in San Francisco Bay and other bay areas. In addition, waterbodies serving as municipal water supplies in several regions are affected by toxics.[15] Most notably, several affected waters in Region 6 supply large municipalities in California and Nevada, including Los Angeles.

CONCLUSIONS

Analysis of California's Water Quality Assessment database and a variety of other sources supports the following conclusions:

- Toxic pollutants adversely affect large areas of surface water in California. Available data suggest that over 800,000 acres of bays, estuaries, lakes, and wetlands are affected by toxics, as are over 3,700 miles of rivers. Most notably, over two-thirds of the assessed area of both bays and saline lakes are thought to be affected by toxics.

- Both point and nonpoint sources play a role in contributing to toxic pollution. Agriculture, primarily agricultural drainage, is the most frequently cited source of pollutants that impair rivers and is also frequently cited as a contributor to the impairment of lakes and reservoirs. Urban runoff and "other" nonpoint sources (e.g., deposition, spills) are most frequently cited as contributing factors to water quality problems in toxics-impaired bays. Mining is the most frequently cited point source, particularly for lakes and reservoirs, while toxics discharged by municipal wastewater treatment plants contribute to the impairment of a variety of waterbody types, particularly estuaries and wetlands.

- Inorganic pollutants such as metals and trace elements are the most significant categories of toxic pollutants affecting waters statewide. Pesticides are also associated with large areas of impairment.

---

[15] Because the available data are not specific, it is possible that the portion of a waterbody from which municipal supplies are drawn may be different from the toxics-affected portion.

- Based on the areal extent of contamination and the uses of affected waterbodies, San Francisco Bay and the Central Valley appear to be the areas most influenced by toxic contamination. In addition, toxics impair a high percentage of river and saline lake area in the Colorado River Basin. While these areas constitute those most extensively affected by toxics, waters in all regions show some degree of toxics impairment.

- Improving the quality of many of the waters impaired by toxics is a high priority for the State. Review of regional basin reports suggests that numerous affected waterbodies currently or formerly supported recreational activity, and several are used for commercial fishing or municipal water supplies. In addition, nearly all of the affected waters serve as wildlife habitat, including habitat for threatened and endangered species.

REFERENCES

State Water Resources Control Board, *Water Quality Assessment*, California Environmental Protection Agency, December 1994.

State Water Resources Control Board, *California 305(b) Report on Water Quality (Draft)*, California Environmental Protection Agency, October 1994.

State Water Resources Control Board, *Bay Protection and Toxic Cleanup Program (Staff Report)*, California Environmental Protection Agency, November 1993.

U.S. EPA, "Analysis of the 1994 California Water Quality Assessment Database," memorandum to Christine Ruf, OPPE, prepared by Matt Schwartz and Bob Black, Industrial Economics, Incorporated, May 21, 1997.

U.S. EPA, *State of the Estuary*, San Francisco Estuary Project, Association of Bay Area Governments, June 1992.

ANGLER HEALTH RISK ASSESSMENT CHAPTER 3

INTRODUCTION

This chapter characterizes the health risks faced by recreational anglers in California as a result of the consumption of fish contaminated by toxics. The chapter also evaluates the angler health benefits associated with meeting the water quality criteria established by the California Toxics Rule (CTR). The analysis begins by estimating health risks under current, or baseline, conditions, evaluating both the carcinogenic and noncarcinogenic (systemic) risks from consumption of fish caught by recreational or subsistence anglers. The analysis then estimates potential reductions in angler health risks by comparing baseline health risks to the proposed criteria's target health risk levels.

It is important to note that we may underestimate some of the angler human health benefits associated with meeting CTR criteria because we have not considered the health risks associated with consuming commercially caught fish. California has commercial fisheries in water bodies covered by this rule, and it is likely that reduced toxics contamination of California waters to meet the CTR criteria will result in some reduced toxic contamination of commercial fisheries. However, because of difficulties in estimating the number of exposed individuals as well as difficulties in linking toxic contamination solely to California sources, we were not able to estimate the baseline health risks and benefits associated with meeting the CTR.

The California Toxics Rule addresses both inland freshwater bodies and enclosed bays and estuaries. This analysis considers two populations of anglers in California who utilize these resources -- inland freshwater anglers and San Francisco Bay anglers. The first group includes all freshwater anglers throughout the state. The second group, San Francisco Bay anglers, is presented as a case study of the baseline health risks for anglers fishing in enclosed bays and estuaries. San Francisco Bay represents one of the most significant non-commercial fisheries among the bays and estuaries covered by the rule. In addition, the Bay has been adversely affected by toxic pollution, as evidenced by the current health advisory warning against consumption of San Francisco Bay sport fish, including striped bass and shark. Despite the issuance of the warning in December 1994, the Bay remains a popular area for anglers.

The potential for health risks from consumption of fish contaminated with toxics is illustrated by the health advisories that have been issued in California warning anglers against consuming fish caught in specific inland waters, bays, and estuaries. Currently, there are 12 fish consumption health advisories in the state: nine in inland waterbodies and three in enclosed bays and estuaries. Exhibit 3-1 provides details for each of these advisories. Inland waterbodies with advisories include rivers, lakes and the Salton Sea. Enclosed bays and estuaries with advisories include San Francisco Bay and Los Angeles/Long Beach Harbor. The advisories in these areas range from avoiding consumption of all species to limiting consumption of specific species. Fish contaminants that are responsible for these advisories include DDT, chlordane, dioxin, mercury, PCBs and selenium.

The baseline assessment of angler health risks has been developed based on current contaminant levels in fish tissue samples collected from San Francisco Bay and freshwater sport fisheries throughout California. The potential health benefits of the rule have been developed by estimating the potential baseline health risks to anglers consuming contaminated fish, and then comparing these to health risks predicted to occur post-rule, assuming waters meet the CTR criteria based on a cancer risk level of 1×10^{-6} for the general population. Since the State of California has the flexibility to choose criteria based on less stringent cancer risk levels, we evaluate the potential health benefits to anglers based on a risk level of 1×10^{-5} for the general population. To more fully evaluate the health benefits of the rule, it would be necessary to estimate the resulting reductions in toxics loadings to surface water and the impact of these reductions on contaminant levels in fish tissue. However, due to the complex interactions between toxics loadings to surface water, toxics in other media (e.g., sediment), and fish tissue contaminant levels, such an analysis is beyond the scope of this effort.

Exhibit 3-1

FISH CONSUMPTION HEALTH ADVISORIES IN CALIFORNIA

Waterbody/Location	Number of Samples in Study Database[1]	Advisory for General Population		Advisory for Sensitive Populations[2]		Contaminants of Concern
		Avoid Consumption	Limit Consumption[3]	Avoid Consumption	Limit Consumption[3]	
New River	12	All species		All species		Pesticides Biological contaminants
Clear Lake (Lake County)	0		1 lb. per month - Largemouth bass over 13" - Channel catfish over 24" - Crappie over 12" 2 lbs. per month - Largemouth bass under 13" 3 lbs. per month - Channel catfish under 24" - Crappie under 12" - White catfish 6 lbs. per month - Brown bullhead - Sacramento blackfish 10 lbs. per month - Hitch	All species		Mercury
Lake Nacimiento (San Luis Obispo County)	0		4 meals per month - Largemouth bass	Largemouth bass		Mercury
Lake Herman (Solano county)	0		1 lb. per month - Largemouth bass	Catfish		Mercury

Exhibit 3-1

FISH CONSUMPTION HEALTH ADVISORIES IN CALIFORNIA

Inland Surface Waters

Waterbody/Location	Number of Samples in Study Database[1]	Advisory for General Population		Advisory for Sensitive Populations[2]		Contaminants of Concern
		Avoid Consumption	Limit Consumption[3]	Avoid Consumption	Limit Consumption[3]	
Lake Berryessa (Napa County)	0		1 lb. per month - Largemouth bass over 15" - Smallmouth bass 2 lbs. per month - Largemouth bass under 15" - White catfish 3 lbs. per month - Channel catfish 10 lbs. per month - Rainbow trout	All fish		Mercury
Guadalupe Reservoir Calero Reservoir Alamaden Reservoir Guadalupe River Guadalupe Creek Alamital Creek Plus associated ponds along these rivers and creeks (Santa Clara County)	0 0 0 0 0 0 0	All fish		All fish		Mercury
Harbor Park Lake (Los Angeles County)	0	Goldfish Carp		Goldfish Carp		DDT Chlordane
Grassland Area Kesterson National Wildlife Refuge (Merced County)	0	Catfish	Max. of 4 oz. every two weeks All fish	All fish		Selenium

Exhibit 3-1

FISH CONSUMPTION HEALTH ADVISORIES IN CALIFORNIA

Waterbody/Location	Number of Samples in Study Database[1]	Advisory for General Population		Advisory for Sensitive Populations[2]		Contaminants of Concern
		Avoid Consumption	Limit Consumption[3]	Avoid Consumption	Limit Consumption[3]	
Inland Surface Waters						
Salton Sea	0		Max. of 4 oz. every two weeks - Croaker - Sargo - Tilapia - Orangemouth Corvina	All fish		Selenium
San Francisco Bay and Estuaries						
San Francisco Bay	64	Striped Bass over 35"	Max. of 2 meals per month - All sport fish	Striped Bass over 27" Shark over 24"	Max. of 1 meal per month All sport fish	Mercury PCBs Dioxins Pesticides
Belmont Pier/Pier J (Los Angeles Harbor)	0		Max. of 2 meals per month - Surfperches			DDT, PCBs
Los Angeles/Long Beach Harbors (esp. Cabrillo Pier)	0	White Croaker	Max. of 2 meals per month - Queenfish - Surfperches - Black Croaker			DDT, PCBs

Notes:

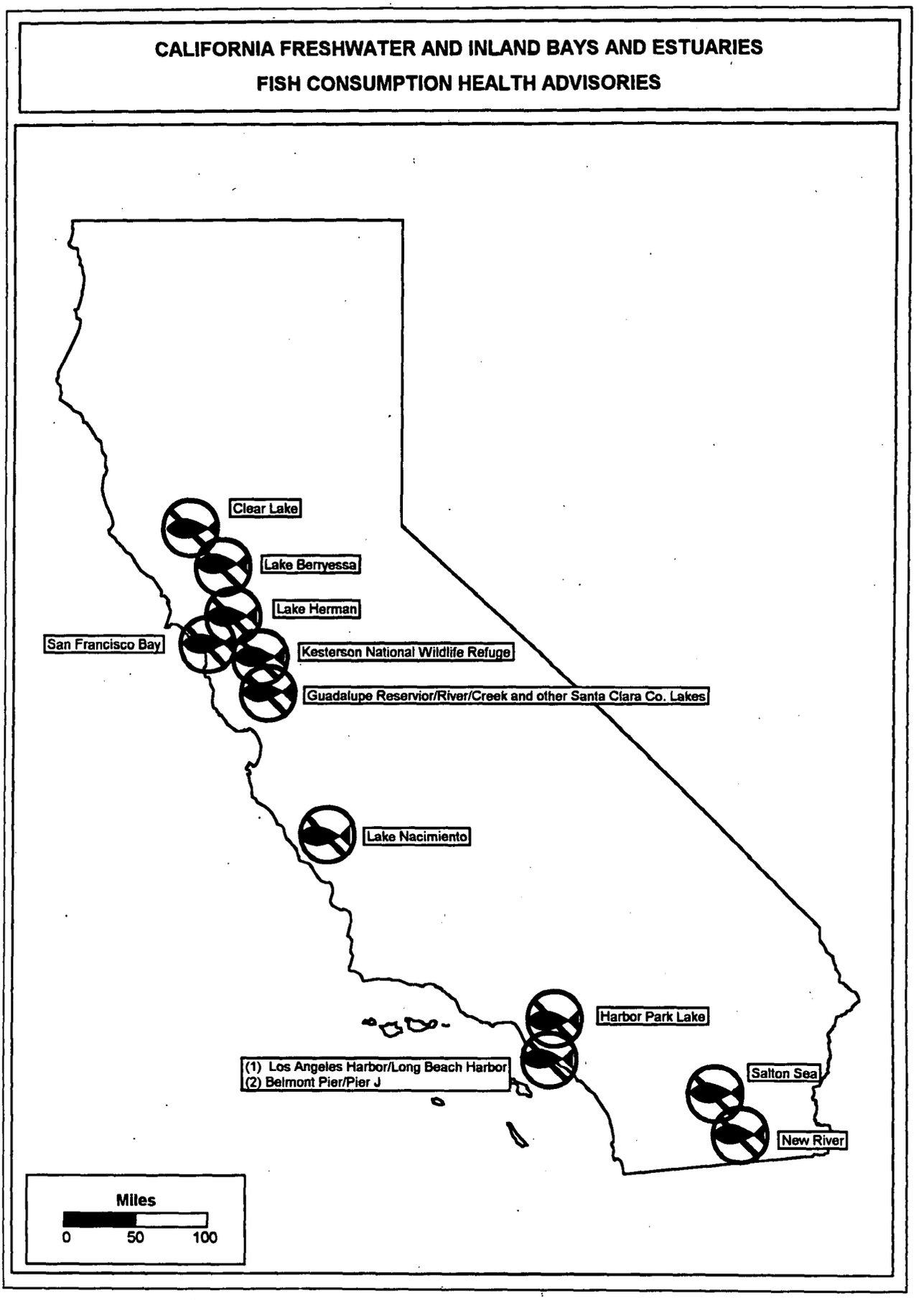
1 Number of samples in the freshwater or San Francisco Bay fish tissue databases developed for this study that were collected from these waterbodies.

2 California EPA defines sensitive populations as women who are pregnant, who may become pregnant, or who are breast-feeding, and children under six years of age.

3 California EPA defines a meal as six to eight ounces (170 grams to 227 grams) of fish for a 154 pound (70 kilogram) individual. Meal size should be adjusted according to body weight (roughly one ounce of fish per 20 pounds of body weight).

4 In addition to these advisories, California EPA has issued consumption warnings for the following ocean sites in Southern California that are not included within the scope of the California Toxics Rule: Newport Pier, Redondo Pier, Malibu Pier, Short Bank, Malibu/Point Dume, Point Vicente, Palos Verdes-Northwest, White's Point, Los Angeles/Long Beach Breakwater (ocean side), and Horseshoe Kelp. Detailed information on these advisories is available in the California Sport Fishing Regulations Handbook.

Exhibit 3-1 (continued)



Summary of Findings

There are potentially significant cancer and noncancer health baseline risks associated with consumption of fish containing toxic pollutants for both freshwater and San Francisco Bay anglers. The cancer and noncancer health risks for these two populations of anglers are summarized in Exhibits 3-2 and 3-3, respectively. Risk levels for freshwater anglers are slightly lower than those for San Francisco Bay anglers, with freshwater angler cancer risks and noncancer risks being roughly 1.2 to 1.5 times less than those for San Francisco Bay anglers.

Summary of Potential Baseline Cancer Risks to Anglers

- Individual excess lifetime cancer risks from fish consumption for freshwater anglers range from 1.5×10^{-4} to 3.5×10^{-4} for typical angler consumption (i.e., 21.4 to 49.6 g/day).[1]

- Upper-bound consumption (i.e., 90th percentile fish consumption of 107.1 g/day) for freshwater anglers results in an individual excess lifetime cancer risk of 7.6×10^{-4}.

- California's freshwater angling population may incur between 5 and 11 cases of cancer each year (based on typical consumption rates and a population of approximately 2.2 million freshwater anglers).

- Current individual excess lifetime cancer risks for typical San Francisco Bay anglers range from 1.8×10^{-4} to 4.3×10^{-4}.

- Upper-bound consumption for San Francisco Bay anglers results in an individual excess lifetime cancer risk of 9.2×10^{-4}.

- San Francisco Bay's angling population may incur less than one to one case of cancer each year, or a total of 23 to 53 cases over 70 years (based on typical consumption and a Bay area angler population of approximately 125,000 individuals).

---

[1] See the section on Risk Assessment and Appendix D for a complete description of the methodology for evaluating cancer health effects.

- The San Francisco Bay case study provides quantitative health risk estimates for 125,000 recreational anglers fishing in the Bay area. The CTR, however, also governs water quality in California's other saltwater inland bays and estuaries. The case study does not include baseline risk estimates for the 500,000 to 600,000 saltwater anglers that fish outside of San Francisco Bay.

These potential baseline cancer risks are dominated by four contaminants. Polychlorinated biphenyls (PCBs) account for nearly 40 percent of the freshwater angler cancer risk. Toxaphene accounts for approximately 20 percent of the risk, while DDT and dieldrin each make up 16 percent of the risk. Two contaminants dominate the San Francisco Bay angler cancer risks. PCBs account for roughly 50 percent of the cancer risk, followed by dioxin contributing 40 percent.

Exhibit 3-2

POTENTIAL BASELINE CANCER RISKS FOR FRESHWATER AND SAN FRANCISCO BAY ANGLERS

	Individual Excess Lifetime Cancer Risk		Annual Population Risk (excess cases per year)[3]
	Typical Consumption[1]	90th Percentile Consumption[2]	
Freshwater Anglers	1.5×10^{-4} - 3.5×10^{-4}	7.6×10^{-4}	5 - 11
San Francisco Bay Anglers	1.8×10^{-4} - 4.3×10^{-4}	9.2×10^{-4}	<1 - 1

1 Typical fish consumption for recreational anglers in California ranges from 21.4 to 49.6 grams/day.
2 90th percentile consumption rate of 107.1 grams/day.
3 Based on typical consumption (21.4 - 49.6 grams/day).

Summary of Potential Baseline Noncancer Risks to Anglers

- The hazard index for freshwater anglers with typical fish consumption (i.e., 21.4 to 49.6 grams per day) ranges from 2.4 to 5.5.[2]

[2] A hazard index greater than 1 indicates the potential for adverse noncancer health effects. See the section on Risk Assessment and Appendix D for a complete description of the methodology for evaluating noncancer health effects.

- The hazard index for freshwater anglers with 90th percentile fish consumption (i.e., 107.1 grams per day) is 11.9.

- The hazard index for San Francisco Bay anglers with typical fish consumption ranges from 3.6 to 8.4.

- The hazard index for San Francisco Bay anglers with 90th percentile fish consumption is 18.1.

Like cancer risks, baseline noncancer risks are dominated by a small number of contaminants. Again, PCBs account for approximately 60 percent of the noncancer risks for freshwater anglers. The hazard quotient for PCBs ranges from 1.4 to 3.3 for typical consumption and 7.0 at the 90th percentile consumption level. Mercury is the only other freshwater contaminant with a hazard quotient greater than 1.0 at the typical 21.4 to 49.6 g/day fish consumption level. Mercury, which has been cited as a contaminant of concern in six of the 12 fish consumption health advisories in California, has a hazard quotient of 0.6 to 1.4 for typical consumption. At the 90th percentile consumption rate, mercury's hazard quotient is 3.1.

PCBs also account for the majority of baseline noncancer risk for San Francisco Bay anglers -- 62 percent. The hazard quotient for PCBs ranges from 2.3 to 5.2 for typical consumption, increasing to 11.3 at the 90th percentile fish consumption level. Mercury has a hazard quotient of 0.75 to 1.74 for typical consumption, accounting for 21 percent of the risk. At 90th percentile consumption, mercury's hazard quotient is 3.8. Dioxin has a hazard quotient of 0.51 to 1.17 at typical consumption levels and accounts for 14 percent of the risk. At 90th percentile consumption, dioxin's hazard quotient is 2.5.

Exhibit 3-3

POTENTIAL BASELINE NONCANCER RISKS FOR FRESHWATER AND SAN FRANCISCO BAY ANGLERS

	Hazard Index	
	Typical Consumption[1]	90th Percentile Consumption[2]
Freshwater Anglers	2.4 - 5.5	11.9
San Francisco Bay Anglers	3.6 - 8.4	18.1

[1] Typical fish consumption for recreational anglers in California ranges from 21.4 to 49.6 grams/day.
[2] 90th percentile consumption rate of 107.1 grams/day.

Potential Benefits of the CTR

An analysis of the CTR's potential health benefits suggests that baseline risks may be reduced substantially if the rule is fully implemented and achieves the target health risk levels associated with the proposed water quality criteria. If the CTR achieves its goals, these reductions would result in a post-rule cancer risk of 1×10^{-6} for the general population. Alternatively, since the State of California has the flexibility to choose criteria based on less stringent cancer risk levels, we have also estimated potential benefits associated with a post-rule cancer risk of 1×10^{-5} for the general population. The potential benefits associated with reductions in cancer and noncancer risks that could accrue as a result of the CTR's implementation are summarized in Exhibits 3-4 and 3-5, respectively.

Summary of Potential Cancer Health Benefits to Anglers

- At criteria based on a 1×10^{-6} risk level for the general population, cancer risks for freshwater anglers would be reduced by 91 percent. If criteria were based on a risk level of 1×10^{-5}, cancer risks for freshwater anglers would be reduced by 37 percent.

- At criteria based on a 1×10^{-6} risk level, the population cancer risk for freshwater anglers would decrease from between 5 and 11 cases per year to approximately one case per year. If criteria were based on a risk level of 1×10^{-5}, the number of cancer cases would be reduced to between three and seven cases per year.

- At criteria based on a 1×10^{-6} risk level, freshwater anglers would have a post-rule individual excess lifetime cancer risk ranging from 1.4×10^{-5} to 3.3×10^{-5} for typical fish consumption. If criteria were based on a risk level of 1×10^{-5}, individual excess lifetime cancer risks would range from 9.4×10^{-5} to 2.2×10^{-4}.

- At criteria based on a 1×10^{-6} risk level, cancer risks for San Francisco Bay anglers would be reduced by 91 percent. If criteria were based on a risk level of 1×10^{-5}, cancer risks for Bay area anglers would be reduced by 55 percent.

- At criteria based on a 1×10^{-6} risk level, the population cancer risk for Bay area anglers would decrease from the baseline of one or fewer cases per year to zero cases per year. If criteria were based on a risk level of 1×10^{-5}, the number of cancer cases would be reduced to between zero and less than one case per year.

- At criteria based on a risk level of 1×10^{-6}, San Francisco Bay anglers would have a post-rule individual excess lifetime cancer risk ranging from 1.7×10^{-5} to 3.8×10^{-5} for typical fish consumption. If criteria were based on a risk level of 1×10^{-5}, individual excess lifetime cancer risks would range from 8.3×10^{-5} to 1.9×10^{-4}.

Exhibit 3-4

POTENTIAL CANCER HEALTH BENEFITS TO RECREATIONAL ANGLERS ASSOCIATED WITH IMPLEMENTATION OF THE CTR[1]

		Post-Rule			
		Achieve Post-Rule Criteria Based on a Risk Level of 1×10^{-6} for the General Population		Achieve Post-Rule Criteria Based on a Risk Level of 1×10^{-5} for the General Population	
	Baseline				
	Individual Excess Lifetime Cancer Risk	Individual Excess Lifetime Cancer Risk	Percent Reduction	Individual Excess Lifetime Cancer Risk	Percent Reduction
Freshwater	1.5×10^{-4} - 3.5×10^{-4}	1.4×10^{-5} - 3.3×10^{-5}	91 %	9.4×10^{-5} - 2.2×10^{-4}	37 %
San Francisco Bay	1.8×10^{-4} - 4.2×10^{-4}	1.7×10^{-5} - 3.8×10^{-5}	91 %	8.3×10^{-5} - 1.9×10^{-4}	55 %

[1] Baseline cancer risks represent 98 percent of the total estimated risk for freshwater anglers and 99 percent of the risk for San Francisco Bay Anglers. All estimates are based on typical consumption (21.4 - 49.6 grams per day).

Summary of Potential Noncancer Health Benefits

- At criteria based on a 1×10^{-6} risk level for the general population, noncancer risks for freshwater anglers would be reduced by 67 percent. If criteria were based on a risk level of 1×10^{-5}, noncancer risks for freshwater anglers would be reduced by 25 percent.

- At criteria based on a 1×10^{-6} risk level for the general population, the hazard index for freshwater anglers would decrease from the baseline of 2.3 to 5.4 to less than 0.8 to 1.8 for typical fish consumption. If criteria were based on a risk level of 1×10^{-5}, the hazard index would range from 1.7 to 4.0.

- At criteria based on a 1×10^{-6} risk level for the general population, mercury would have the highest post-rule hazard quotient for an individual freshwater contaminant -- 0.6 to 1.4 for typical consumption. If criteria were based on a risk level of 1×10^{-5}, PCBs would have a HQ of 0.8 to 1.9 while mercury's HQ would range from 0.6 to 1.4. All other freshwater contaminants would have hazard quotients of less than one under both post-rule scenarios.

- At criteria based on a 1×10^{-6} risk level for the general population, noncancer risks for San Francisco Bay anglers would be reduced by 76 percent. If criteria were based on a risk level of 1×10^{-5}, noncancer risks for Bay area anglers would be reduced by 49 percent.

- At criteria based on a 1×10^{-6} risk level for the general population, the hazard index for Bay area anglers would decrease from the baseline of 3.5 to 8.2 to less than 0.9 to 2.0 for typical fish consumption. If criteria were based on a risk level of 1×10^{-5}, the hazard index would range from 1.8 to 4.2.

- At criteria based on a 1×10^{-6} risk level for the general population, mercury would have the highest post-rule hazard quotient for an individual San Francisco Bay contaminant -- 0.8 to 1.7 for typical consumption. If criteria were based on a risk level of 1×10^{-5}, PCBs would have a HQ of 0.8 to 1.9 while mercury's HQ would range from 0.8 to 1.7. All other Bay area contaminants would have hazard quotients of less than one under both post-rule scenarios.

Exhibit 3-5

POTENTIAL NONCANCER HEALTH BENEFITS TO RECREATIONAL ANGLERS ASSOCIATED WITH IMPLEMENTATION OF THE CTR[1]

	Baseline	Post-Rule: Achieve Post-Rule Criteria Based on a Risk Level of 1×10^{-6} for the General Population		Post-Rule: Achieve Post-Rule Criteria Based on a Risk Level of 1×10^{-5} for the General Population	
	Individual Hazard Index	Individual Hazard Index	Percent Reduction	Individual Hazard Index	Percent Reduction
Freshwater	2.31 - 5.39	0.76 - 1.77	67 %	1.73 - 4.00	25 %
San Francisco Bay	3.52 - 8.18	0.85 - 1.98	76 %	1.79 - 4.16	49 %

[1] Baseline cancer risks represent 98 percent of the total estimated risk for freshwater anglers and 99 percent of the risk for San Francisco Bay Anglers. All estimates are based on typical consumption (21.4 - 49.6 grams per day).

Uncertainties

The analysis of angler health risks involves a series of assumptions that are generally designed to characterize typical recreational anglers. To the extent that anglers differ from this characterization, the analysis may over- or underestimate risk. Some of the areas of potential uncertainty include consumption rates, mixing of species in an individual's diet, and assigning concentration values to contaminants in samples in which they were not detected. We addressed these assumptions by developing ranges of potential exposure values. In the case of consumption rates, we present results based on reasonable bounds for typical consumption and for 90th percentile consumption. With respect to species mixing and nondetected values, we have conducted sensitivity analyses to characterize the magnitude of these uncertainties. These analyses are presented throughout the chapter.

Other uncertainties, especially those affecting subpopulations, could not be fully characterized within this analysis. These include ethnic and income effects on consumption rates, fish preparation methods, and risks to family members. We reviewed our standard assumptions against information provided in the relevant literature on angler subpopulations to determine the potential effects each of these uncertainties has on the analysis. Additional information for each of these areas and the results of our literature review are summarized at the end of this chapter.

Finally, we may have underestimated some of the angler human health benefits associated with meeting CTR criteria because we have not considered the health risks associated with consuming commercially caught fish. California has commercial fisheries in water bodies covered by this rule, and it is likely that reduced toxics contamination of California waters to meet the CTR criteria will result in some reduced toxic contamination of commercial fisheries. However, because of difficulties in estimating the number of exposed individuals as well as difficulties in linking toxic contamination solely to California sources, we were not able to estimate the baseline health risks and benefits associated with meeting the CTR.

Organization of Chapter

The remaining sections of this chapter provide detailed information on our health risk analysis. First, we describe the general method used to estimate the baseline health risks for both freshwater and San Francisco Bay anglers. In the second and third sections, we describe the specific analyses of the health risks for each of these populations. These sections include discussions of data sources, exposure assumptions, and uncertainties in the health risk estimates for these two populations. The fourth section addresses environmental justice concerns related to the exposure of California anglers to toxic contaminants in fish tissue. The fifth section describes some of the general uncertainties in assessing health risks to anglers that are relevant to both the freshwater and San Francisco Bay analyses. The sixth section describes potential reductions in angler health risks associated with meeting the water quality criteria established by the California Toxics Rule. The final section summarizes our findings.

METHODOLOGY FOR ESTIMATING RECREATIONAL ANGLER RISK

This section describes our general approach to estimating the potential health risks to anglers in California from consuming the fish they catch in freshwater and in San Francisco Bay. We have estimated both the cancer and noncancer health risks associated with exposure to contaminants limited to the California Toxics Rule. Specific descriptions of the methods and assumptions used to assess the risks for freshwater and San Francisco Bay anglers are provided in the following sections of this chapter. The general steps in estimating these risks are:

- Determining arithmetic mean contaminant levels in fish tissue that is consumed by anglers;
- Assessing potential angler exposure to these contaminants; and
- Calculating the potential risks associated with exposure.

Fish Tissue Contaminant Levels

The first step in analyzing potential angler health risks was to obtain fish tissue contaminant data. Detailed descriptions of the fish tissue databases selected for this assessment are presented in Appendix B. Each of the databases selected for this analysis meet the following general criteria:

- They contain data on recently collected samples that reflect current contaminant levels -- the freshwater fish tissue data were collected between 1988 and 1993; San Francisco Bay fish tissue data were collected in May and June 1994;
- They provide data on the concentration of contaminants found in fish fillets, which are the most commonly eaten portion of fish;
- They provide data on fish species that are commonly caught and consumed by anglers in California.

For both the freshwater and San Francisco Bay analyses, we calculated the mean concentration of contaminants in fish tissue solely for those contaminants that will be addressed by the California Toxics Rule. All contaminants that are not addressed by this rule, including those already regulated under the National Toxics Rule for the specific locations considered in this analysis, have been excluded from our estimates of angler health risks.[3]

---

[3] Under the National Toxics Rule (57 FR 60848-60923), EPA promulgated water quality criteria for selected pollutants in certain waters within the State of California. For example, the rule establishes a criterion for selenium in the waters of the San Joaquin River (between Sack Dam and Vernalis), Salt Slough and Mud Slough. In calculating freshwater angler health risks associated with selenium concentrations in fish tissue, we excluded any samples collected in these waterbodies.

We calculate arithmetic mean contaminant concentrations for individual species of fish represented in the freshwater and San Francisco Bay databases. In calculating these values, we follow the standard EPA practice of using one-half of the method detection limit (MDL) for samples in which contaminants were reported as not detected.[4] However, in cases where a contaminant is not detected in any sample within the database, we conclude that the contaminant is not present. We employ sensitivity analysis to determine the impact of this assumption on our findings.

Exposure Assessment

The next step in calculating potential health risks for anglers is to determine their exposure to individual contaminants found in fish tissue. Exposure can be calculated from the fish tissue contaminant concentration and the fish consumption rate. The general equation for calculating average daily dose on a body weight basis is shown below.

$$\frac{\text{Fish Tissue Contaminant Concentration (mg/kg)} \times \text{Fish Consumption Rate (kg/day)}}{\text{Body Weight (kg)}} = \text{Dose (mg/kg-day)}$$

Since this is a health risk assessment for anglers, the consumption rate should reflect the habits of this population, rather those of the general population. As a group, anglers tend to consume larger quantities of fish than the general population. EPA guidance on evaluating risks associated with fish consumption reports that the general population consumes an average of 6.5 g/day of fish. Numerous studies evaluate consumption among anglers, and all estimate substantially higher consumption rates for anglers compared to the general population. EPA offers default values, but recommends using local consumption data whenever they are available.[5]

---

[4] USEPA, *Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories: Volume 1, Fish Sampling and Analysis*, Office of Water, EPA 823-R-93-002, August 1993.

[5] USEPA, *Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories, Volume 1: Fish Sampling and Analysis*, Office of Water, EPA 823-R-93-002, August 1993.

A 1994 survey of fish consumption patterns among anglers in Santa Monica Bay provides recent estimates of consumption rates for California anglers.[6] The results of this study, conducted by the Santa Monica Bay Restoration project, are based on interviews with 554 anglers fishing from beaches, piers, private boats, party boats, and charter boats to determine the level and nature of sport-caught fish consumption. Although these estimates were developed by interviewing only consuming anglers, EPA applied them to total anglers because they are supported by fish consumption rates for all anglers reported in other studies.[7] In addition, representatives of the California EPA's Office of Environmental Health Hazard Assessment (OEHHA) consider the Santa Monica study applicable to anglers throughout the state.[8]

We use the Santa Monica Bay study for three estimates of fish consumption rates among California anglers. We assume that a "typical" California angler consumes between 21.4 and 49.6 grams of fish per day. This range is bounded by the median (21.4 g/day) and the mean (49.6 g/day) from the Santa Monica Bay study. This range covers the entire central portion of the study's fish consumption distribution, so we assume that the vast majority of California anglers consume fish within these rates. We present all estimates of potential individual and population risks (cancer and noncancer) based on this range.

We also provide individual risk estimates for anglers at the high end of the fish consumption distribution. Based on the Santa Monica Bay study, we use the 90th percentile consumption rate of 107.1 g/day to represent these high consumption anglers. The 90th percentile value may also be representative of subgroups of anglers, such as those relying on their fish catch for subsistence, or those from a specific ethnic group, whose diets contain substantially more fish than other anglers'. Appendix C compares each of the study's consumption rates to those reported in other representative studies.

Another issue in calculating exposure to fish tissue contaminants is the species composition of angler fish diets. Angler fishing and consumption habits can vary. Some anglers catch and consume a mix of species. To calculate exposures for these anglers, it is necessary to develop a

---

[6] Santa Monica Bay Restoration Project, *Santa Monica Bay Seafood Consumption Study*, prepared by Southern California Coastal Water Research Project and MBC Applied Environmental Sciences, June 1994.

[7] See Appendix C for a summary of these other sport-fish consumption studies.

[8] Dr. Gerald Pollack, Office of Environmental Health Hazard Assessment, California EPA, personal communication, August 1995.

species-weighted contaminant concentration that reflects the relative contribution of different species to their diet. Other anglers target their efforts toward catching a single species. For these anglers, we would expect their preferred species to account for virtually all of their fish consumption. Therefore, exposures for these anglers can be calculated from mean contaminant concentrations for individual preferred species. Accordingly, we have estimated angler exposure to fish tissue contaminants based on both mixed species and single species diets. The specific approaches for deriving the average contaminant concentrations for the mixed species diets are described separately for each angler group.

Risk Assessment

The final step in this analysis is to calculate the potential cancer and noncancer risks from the estimated exposures to contaminants in fish tissue. The approach to calculating risk is briefly described below. A more detailed description of the risk assessment approach, including limitations and uncertainties, is presented in Appendix D.

Risk assessors express cancer effects in terms of individual excess lifetime cancer risk (ILCR). The ILCR is calculated for each contaminant by multiplying the dose by the cancer slope factor (CSF), which is the slope of the cancer dose-response curve. The risks for the individual contaminants are then summed to produce the total ILCR. In promulgating water quality criteria, EPA generally considers a ILCR of 1×10^{-6} (i.e., each individual faces a 1 in 1,000,000 chance of contracting cancer over a lifetime) sufficient to protect the general population.

Multiplying the ILCR by the total population exposed and dividing by the typical life span of 70 years produces an estimate of the population cancer risk, expressed as the annual number of cancer cases. The calculation of individual and population cancer risks are summarized in the following equations.

$$Dose\ (mg/kg\text{-}day)\ x\ CSF\ (mg/kg\text{-}day)^{-1} = ILCR$$

$$\frac{ILCR\ x\ Population\ Size}{70\ years} = \begin{array}{c} Annual\ Population \\ Cancer\ Risk \\ (cases\ per\ year) \end{array}$$

Noncancer health effects are assumed to be additive and are assessed by means of a hazard index (HI). The HI is the sum of hazard quotients (HQs) for individual contaminants and is described in Appendix D. As shown in the equations below, the HQ is calculated by dividing the dose by the reference dose (RfD), where the RfD represents the dose below which no adverse health effects are expected over a lifetime exposure. Thus, an HI of 1.0 implies that contaminant exposures exceed the established threshold of toxicity, indicating the potential for adverse health effects.

$$\frac{Dose\ (mg/kg\text{-}day)}{RfD\ (mg/kg\text{-}day)} = HQ$$

$$\sum HQ\ (for\ individual\ contaminants) = HI$$

In the following two sections, we describe how these methods were applied in assessing health risks for freshwater and San Francisco Bay anglers. We also present the results of the analysis for these two angler populations.

FRESHWATER ANGLERS

This section describes the specific methods and assumptions used to estimate the potential health risks associated with exposure to contaminants present in freshwater fish tissue. In addition, we discuss the results of this analysis and the primary uncertainties in the health risk estimate for freshwater anglers.

Fish Tissue Contaminant Levels

Freshwater fish tissue contaminant levels were obtained from California's Toxic Substances Monitoring Program (TSMP). This program monitors the occurrence of toxic pollutants in California's waters through sampling and analysis of fish tissue. The TSMP includes freshwater tissue samples collected throughout the state. For purposes of this analysis, we selected all of the available data collected from 1988 to 1993. This included over 360 samples of 32 different freshwater fish species. We combined these 32 individual species into five broad groups: trout, bass, catfish, panfish and other. We review the TSMP, including waterbodies sampled, in Appendix B.

The TSMP data provide broad coverage of freshwater resources within the state of California. Fish tissue samples collected from locations within each of the nine State Water Control Board Regions were used in this analysis. Exhibit 3-6 shows how the 224 sampling locations for metals and 170 sampling locations for organics were distributed across these regions. Despite this wide representation of freshwater bodies, the database may not provide a representative sample of the impact of water quality in California on fish tissue contaminant concentrations. This occurs because fish tissue sampling under this program generally has been targeted to waterbodies with known or suspected water quality impairments. Thus, the data in the TSMP may tend to overstate contaminant levels in freshwater fish in California.

A review of the TSMP sampling stations included within this analysis indicates that the program's potential bias may not be significant. First, across the entire state, approximately 53 percent of the waterbodies (encompassing 51 percent of the fish tissue samples) included in the freshwater analysis are currently expected to meet applicable water quality criteria. Second, each of the California Water Quality Control Board regions samples impaired waterbodies at different rates. Regions 4, 6, and 8, for example, collect between 75 and 95 percent of their samples from impaired waterbodies. The six remaining regions collect between eight and 38 percent of their samples from impaired sources. Analysis of sample size by region, however, indicates that regions with a large number of samples from impaired waters are not likely to exert a disproportionate impact on average tissue concentrations because the number of samples collected in these regions is generally equal to or less than the number of samples collected in other regions.

Exhibit 3-6

DISTRIBUTION OF FISH TISSUE SAMPLING LOCATIONS ACROSS CALIFORNIA STATE WATER QUALITY CONTROL BOARD REGIONS

Region	Number of Sampling Locations	
	Metals	Organics
Region 1	19	15
Region 2	16	11
Region 3	25	18
Region 4	27	27
Region 5	44	27
Region 6	41	16
Region 7	21	22
Region 8	6	9
Region 9	25	25
Total	224	170

Similarly, comparison of TSMP sampling locations to areas where California's OEHHA has issued health advisories warning against fish consumption shows that less than three percent of the samples (12 out of more than 360 samples) used in this analysis were collected from locations where advisories had been issued. These results also suggest that any bias toward higher fish tissue contaminant levels introduced by this targeted sampling effort may be limited.

The TSMP database contains concentration data for 15 different contaminants covered by the California Toxics Rule, including both metals and organic compounds. Of these, eight are classified by EPA as carcinogens and 13 (including six of the eight carcinogens) are associated with noncarcinogenic effects. Exhibit 3-7 lists the cancer slope factor (CSF), weight of evidence for carcinogenicity, reference dose (RfD), and specific target organs for each of these contaminants. These toxicity values were used in calculating the health risks associated with freshwater angler fish consumption.

For this analysis, we applied a CSF of 2.0 mg/kg-day for polychlorinated biphenyls (PCBs) based on EPA's revised October 1, 1996 guidance for assessment of carcinogenic human health risks associated with PCB exposure. EPA's revised guidance recommends a tiered approach that uses PCB CSFs ranging from 0.04 to 2.0 mg/kg-day depending on the characteristics of the exposure pathway and congener composition of the PCB mixture. EPA notes that bioaccumulated congeners ingested through the food chain (e.g., consumption of recreationally caught fish) tend to exhibit the highest chlorine content and persistence. Therefore, EPA recommends using the highest PCB CSF of 2.0 mg/kg-day for food chain exposure pathways where environmental processes tend to increase risk.[9]

It is also important to note that the TSMP does not analyze fish tissue samples for dioxin and furan. In 1992, however, EPA's *National Study of Chemical Residues in Fish* identified dioxins and furans in fish tissues collected from several freshwater locations in California.[10] While the EPA study targeted most sampling sites based on their high potential for dioxin and furan contamination, these results indicate the potential for dioxin health risks may exist throughout California's freshwaters. Therefore, to the extent that dioxin and furans exist in California's freshwater fish tissues, this assessment may understate angler health risks and benefits.

---

[9] USEPA, National Center for Environmental Assessment, Office of Research and Development. *PCBs: Cancer Dose-Response Assessment and Application to Environmental Mixtures*, EPA/600/P-96/001F, September 1996.

[10] USEPA. *National Study of Chemical Residues in Fish, Volumes I and II.* Office of Science and Technology, EPA 823-R-92-008a,b, September 1992.

Exposure Assumptions

Consumption Rate

As previously discussed, potential health risks were estimated for "typical" California anglers and high consumption individuals. For typical anglers, we assumed a consumption rate range of 21.4 to 49.6 g/day. We characterized high end consumption as the 90th percentile of the population, or 107.1 g/day. Population risks (for cancer effects only) were calculated using the typical angler consumption range to reflect average consumption across the entire population.

To estimate potential exposure to fish tissue contaminants it is necessary to derive appropriate measures of mean contaminant levels that reflect the relative proportion of individual species in anglers' diets. As shown in Exhibit 3-8, species-weighted contaminant concentrations were developed from estimates of fishing activity and keep rates by species.[11] Estimates of the fishing activity for California freshwater anglers, expressed as the number of fishing days per year that anglers attempt to catch a certain species, were obtained from the U.S. Fish and Wildlife Service's (FWS) *1991 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation, California.* Trout account for the largest percentage of fishing days followed by bass and catfish. Panfish and other species account for the smallest percentage of the fishing days. Keep rates were obtained from data collected by the California Department of Fish and Game (CDFG) through its Sacramento River Sport Fish Catch Inventory Project.[12] Based on four years of angler survey data on the Sacramento, American, Feather, and Yuba Rivers, keep rates are highest for panfish and catfish, roughly 90 percent and 80 percent, respectively. Keep rates for bass and trout were significantly lower, at 20 percent to 25 percent. For purposes of this analysis, we assumed that keep rates for these two species, as well as for "other" species, were all 25 percent.[13]

When fishing activity by species is adjusted according to keep rate, catfish become the largest contributor to anglers' diets, accounting for nearly 35 percent. The contribution of trout to anglers' diets is 28 percent. Bass and panfish contribute roughly equal proportions of the diet (16 percent and 18 percent, respectively). Other species represent less than five percent of the diet.

---

[11] Ideally, the contribution of each species to anglers' diets would be calculated by multiplying fishing activity (number of days) by catch rates and keep rates. We were unable to obtain estimates of state-wide catch rates by species. In lieu of this information, we assumed that catch rates do not vary across species.

[12] California Department of Fish and Game Inland Fisheries Division, *Sacramento River System Sport Fish Catch Inventory, Final Performance Report*, June 30, 1995.

[13] Dennis Lee, California Department of Fish and Game, personal communication, August 1995.

Exhibit 3-7

TOXICITY VALUES FOR CONTAMINANTS IN FRESHWATER FISH TISSUE

Contaminant	CSF[1] (mg/kg-day)	Cancer Weight[2] of Evidence	RFD[3] (mg/kg-day)	Target Organ
Copper	NA	D	3.7×10^{-2}	Gastro-intestinal tract
Mercury	NA	C	1.0×10^{-4}	Central nervous system (CNS)
Nickel	NA	NA	2.0×10^{-2}	Decreased body and organ weight
Selenium	NA	D	5.0×10^{-3}	Selenosis (liver, blood, CNS)
Zinc	NA	D	3.0×10^{-1}	Blood
Chlordane	1.3	B2	6.0×10^{-5}	Liver
DDT	0.34	B2	5.0×10^{-4}	Liver
Dieldrin	16.0	B2	5.0×10^{-5}	Liver
Endosulfan	NA	NA	6.0×10^{-3}	Kidney, CNS, circulatory system, increased body weight
Endrin	NA	D	3.0×10^{-4}	Liver, CNS
HCH-alpha	6.3	B2	NA	NA
HCH-gamma	1.3	B2-C	3.0×10^{-4}	Liver, kidney
Hexachlorobenzene	1.6	B2	8.0×10^{-4}	Liver
PCBs[4]	2.0	B2	2.0×10^{-5}	Immune system, reproductive system, liver, skin
Toxaphene	1.1	B2	NA	NA

Source: Toxicity values obtained from USEPA's *Integrated Risk Information System* (4th Quarter, 1996), except for the copper and the HCH-gamma CSFs, which were obtained from USEPA's *Health Effects Assessment Summary Table*, 1994.

1 Cancer Slope Factor.
2 See Appendix D for definitions of weight of evidence.
3 Reference Dose.
4 PCBs are calculated as the sum of Aroclors 1248, 1254, and 1260; individual PCB congener concentrations were not available in the TSMP database. The RfD for PCBs is based on Aroclor 1254.

Exhibit 3-8

SPECIES WEIGHTS FOR FRESHWATER FISH CONSUMPTION

Species	Annual Fishing Activity[1] (number of days)	Keep Rate[2]	Keep Rate Weighted Days	Consumption[3] Weighting Factors
Trout	10,641	25%	2,660	28.0%
Bass	6,164	25%	1,541	16.2%
Catfish	4,098	80%	3,278	34.6%
Panfish	1,866	90%	1,679	17.7%
Other	1,315	25%	329	3.5%
Total	24,084		9,487	100 %

1 Fishing Activity obtained from *National Survey of Fishing, Hunting, and Wildlife-Associated Recreation, California, 1991*, USFWS.
2 Keep rate estimated from *Sacramento River Sport Fish Catch Inventory Project, Final Performance Report*, CDFG, 1995.
3 Calculated by dividing the Keep Rate Weighted Days for each species by the Total Keep Rate Weighted Days.

Angler Population

We estimated a population of 2,244,371 full-time equivalent freshwater anglers in California.[14] We calculated this freshwater angler population based on data reported by the U.S. Fish and Wildlife Service (F&WS) in the *1991 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation* and license sales reported by the California Department of Fish and Game.

According to the F&WS survey, there are approximately 3,607,500 resident anglers in California. Of these, 2,499,600 are adult resident anglers and 1,107,900 are resident anglers between the ages of six and 15. These anglers split their fishing activity between fresh and saltwater. The F&WS study reports that approximately 60.8 percent of California's adult anglers fish exclusively in freshwater, 19.5 percent fish exclusively in saltwater, and 19.7 percent split their activity between

[14] To calculate the number of full-time equivalent freshwater anglers in California we add the number of anglers who fish exclusively in freshwater to one-half the number of anglers who fish in both freshwater and saltwater.

fresh and saltwater.[15] We have assumed that anglers who have mixed fishing activity split their effort equally between fresh and saltwater. Based on these proportions and the total angler population, we estimate that there are 1,058,801 saltwater anglers and 2,548,699 freshwater anglers in California.

We further adjust the freshwater angler population downward to reflect the infrequent anglers included in the results of the F&WS study. We remove these anglers from the population risk estimate because they are unlikely to satisfy the exposure criteria used to calculate individual health risks (e.g., consumption of 21.4 to 49.6 grams of fish per day for a lifetime). The F&WS study, however, does not provide detailed information on fishing frequency. Accordingly, we net out infrequent angler activity using data on the number of one-day fishing licenses sold in California in 1991. Specifically, based on 1991 one-day license sales, we reduce the freshwater angler population by an additional 304,328 to reflect the infrequent anglers included in the F&WS estimate. This estimate includes several assumptions. First, since one-day licenses entitle anglers to fish in both fresh and saltwater, we assume the same proportions identified above to adjust the license data to freshwater equivalents. Further, these license data only reflect adult angling activity since anglers ages six to 15 are not required to obtain a license to fish in California. As a result, we assume that the proportion of one-day anglers with ages six to 15 is identical to the proportion of one-day licenses purchased by adult freshwater anglers.

Potential Angler Health Risks

Our estimates of potential cancer risks associated with exposure to all eight carcinogenic contaminants at concentrations currently found in freshwater fish are presented in Exhibit 3-9. The total ILCR for typical anglers consuming a mixed species diet ranges from 1.5×10^{-4} to 3.5×10^{-4}. At the 90th percentile consumption level, a mixed species diet results in an ILCR of 7.6×10^{-4}. The population cancer risk ranges from 5 to 11 cases per year. These risks are dominated by four contaminants. PCBs account for 37 percent of the cancer risk, ranging from 5.6×10^{-5} to 1.3×10^{-4} under the typical consumption scenario. Toxaphene risk ranges from 3.2×10^{-5} to 7.5×10^{-5} under typical consumption, and accounts for 21 percent of the cancer risk. DDT and Dieldrin each account for 16 percent of the cancer risk.

---

[15] The F&WS study does not provide comparable percentages for children (i.e., anglers aged six to 15). For the purposes of calculating the total exposed population, we assume that children divide their fishing activity among waterbody types in the same proportions as adult anglers.

Exhibit 3-9

POTENTIAL BASELINE CANCER RISK FOR RECREATIONAL ANGLERS CONSUMING FRESHWATER FISH IN CALIFORNIA

Contaminant	Individual Excess Lifetime Cancer Risk: Typical Consumption (21.4 - 49.6 g/day)	Individual Excess Lifetime Cancer Risk: 90th Percentile Consumption (107.1 g/day)	Population Cancer Risk[1] (excess cases per year)	Relative Contribution
PCBs	5.6×10^{-5} - 1.3×10^{-4}	2.8×10^{-4}	2 - 4	37.0 %
Toxaphene	3.2×10^{-5} - 7.5×10^{-5}	1.6×10^{-4}	1 - 2	21.2 %
DDT	2.5×10^{-5} - 5.8×10^{-5}	1.3×10^{-4}	1 - 2	16.6 %
Dieldrin	2.4×10^{-5} - 5.6×10^{-5}	1.2×10^{-4}	1 - 2	16.0 %
Chlordane	1.1×10^{-5} - 2.5×10^{-5}	5.3×10^{-5}	<1- 1	7.0 %
HCH-alpha	2.0×10^{-6} - 4.6×10^{-6}	1.0×10^{-5}	<1 - <1	1.3 %
Hexachlorobenzene	1.0×10^{-6} - 2.4×10^{-6}	5.1×10^{-6}	<1 - <1	0.7 %
HCH-gamma	4.6×10^{-7} - 1.1×10^{-6}	2.3×10^{-6}	<1 - <1	0.3 %
Total	**1.5×10^{-4} - 3.5×10^{-4}**	**7.6×10^{-4}**	**5 - 11**	**100 %**

[1] Based on typical fish consumption (21.4 to 49.6 g/day) and a freshwater angler population of 2,244,371. Values rounded to the nearest cancer case.

Noncancer risks for freshwater anglers are summarized in Exhibit 3-10. The HI for typical consumption ranges from 2.4 to 5.5. At 90th percentile consumption levels, the HI is 11.9. As with cancer risks, noncancer risks are dominated by a small number of contaminants. The HQ for PCBs under typical consumption ranges from 1.4 to 3.3; at 90th percentile consumption PCBs have an HQ of 7.0. Mercury has an HQ of 0.6 to 1.4 under typical consumption; at 90th percentile consumption mercury has an HQ of 3.1. Together, PCBs and mercury account for 85 percent of the noncancer risk. No other contaminant has an HQ that is greater than one under any of the consumption scenarios. DDT and chlordane, however, each have HQs of 0.7 at 90th percentile consumption, suggesting the potential for adverse effects for anglers with high consumption rates. The specific noncancer effects associated with these contaminants are listed above in Exhibit 3-7 and described in Appendix D.

Exhibit 3-10

POTENTIAL BASELINE NONCANCER RISK FOR RECREATIONAL ANGLERS CONSUMING FRESHWATER FISH IN CALIFORNIA

Contaminant	Hazard Quotient		Relative Contribution
	Typical Consumption (21.4 - 49.6 g/day)	90th Percentile Consumption (107.1 g/day)	
PCBs	1.40 - 3.30	7.02	58.9 %
Mercury	0.62 - 1.44	3.12	26.1 %
DDT	0.15 - 0.34	0.74	6.2 %
Chlordane	0.14 - 0.31	0.68	5.7 %
Dieldrin	0.03 - 0.07	0.15	1.3 %
Selenium	0.02 - 0.06	0.12	1.0 %
Endrin	0.01 - 0.02	0.04	0.3 %
Endosulfan	<0.01 - 0.01	0.02	0.2 %
Zinc	<0.01 - 0.01	0.02	0.2 %
Copper	<0.01 - <0.01	0.01	0.1 %
HCH-gamma	<0.01 - <0.01	0.01	<0.1 %
Nickel	<0.01 - <0.01	0.01	<0.1 %
Hexachlorobenzene	<0.01 - <0.01	<0.01	<0.1 %
Hazard Index	**2.38 - 5.52**	**11.92**	**100 %**

To determine whether anglers who catch and consume a single species are not subject to disproportionate risks, we also calculated health risk based on mean contaminant concentrations for each of the five freshwater species groups. The species-specific health risks are shown in Exhibit 3-11. Cancer risks for single species diets vary by no more than a factor of 2.4 from the risk associated with a mixed species diet. A fish diet consisting entirely of "other" species produces the highest cancer risk. Based on typical consumption, the risk associated with a diet of "other" species ranges from 3.6×10^{-4} to 8.3×10^{-4}, approximately two times higher than the species-weighted risk. Panfish pose the lowest risk, ranging from 9.1×10^{-5} to 2.1×10^{-4} at typical consumption rates, about 1.6 times less than the species-weighted risk.

Similarly, noncancer risks for single species diets differ from the risk associated with a mixed species diet by similar proportions. "Other" species pose the highest risk with an HI ranging from 4.0 to 9.3 for typical anglers, again approximately two times greater than the species-weighted HI of 2.4 to 5.5. Trout pose the lowest noncancer risk, an HI of 1.8 to 4.3, only 1.3 times less than the species-weighted HI.

Exhibit 3-11

POTENTIAL BASELINE HEALTH RISKS ASSOCIATED WITH CONSUMPTION OF DIFFERENT FRESHWATER SPECIES IN CALIFORNIA

	Individual Excess Lifetime Cancer Risk		Noncancer Risk (Hazard Index)	
Species	Typical Consumption (21.4 - 49.6 g/day)	90th Percentile Consumption (107.1 g/day)	Typical Consumption (21.4 - 49.6 g/day)	90th Percentile Consumption (107.1 g/day)
Other	3.6×10^{-4} - 8.3×10^{-4}	1.8×10^{-3}	4.0 - 9.3	20.1
Catfish	2.3×10^{-4} - 5.4×10^{-4}	1.2×10^{-3}	2.8 - 6.4	13.9
Bass	1.0×10^{-4} - 2.3×10^{-4}	5.0×10^{-4}	2.6 - 5.9	12.8
Trout	9.2×10^{-5} - 2.1×10^{-4}	4.6×10^{-4}	1.8 - 4.3	9.2
Panfish	9.1×10^{-5} - 2.1×10^{-4}	4.6×10^{-4}	2.0 - 4.6	10.0
Species-Weighted Value	1.5×10^{-4} - 3.5×10^{-4}	7.6×10^{-4}	2.4 - 5.5	11.9

Uncertainties

The methodology used to estimate baseline health risks for freshwater anglers includes a series of assumptions that introduce uncertainty into the results of this analysis. Some of these assumptions apply to the analyses of both freshwater and San Francisco Bay anglers, while others are specific to the freshwater angler analysis. The impacts of uncertainties related to two key assumptions in the freshwater angler analysis are described below. These uncertainties arise from the following elements of the freshwater angler analysis:

- Deriving species weights that reflect the relative contribution of individual species to the freshwater angler fish diet; and

- Assigning concentration values to contaminants for samples in which they were not detected above the MDL.

Additional uncertainties that are relevant to both the freshwater and San Francisco Bay angler analysis will be discussed in a later section of this chapter.

Species Weights

The relative contribution of individual species to freshwater anglers' fish diets is based on several assumptions. First, by using the keep rates from the Sacramento River Inventory Project, we have assumed that keep rates for species are consistent across all freshwater fisheries in California. Second, in lieu of having estimates of species-specific catch rates, we assumed that catch rates were uniform across all species. Despite these uncertainties, the assumptions used to develop species weights are unlikely to significantly over- or underestimate freshwater angler health risks, because the difference between the species-weighted risk and the risk for each individual species is relatively small. Based on the maximum and minimum risks for each species, any change in the relative contribution of individual species to the total fish diet could increase the species-weighted cancer risk by no more than a factor of 2.4, or decrease it by no more than a factor of 1.6. Cancer risk would be greater than 1×10^{-5} in all cases. Noncancer risks could increase by no more than a factor of 1.7 or decrease by a maximum factor of 1.3. In all cases, the noncancer hazard index would remain above 1.0.

Contaminants Not Detected Above MDLs

In calculating the average fish tissue concentrations used to estimate health risks for freshwater anglers, we assume that all contaminants not detected in specific fish tissue samples above Method Detection Limits (MDLs) are present at concentrations equal to one-half of the MDL. As discussed above, this is a standard but somewhat conservative approach. A nondetect value means that a contaminant is not present above the MDL, but does not mean that it may not be present at some concentration below this level. Therefore, a sample in which a contaminant is not detected either does not contain the contaminant, or contains the contaminant at a concentration less than the detection limit. We conducted a sensitivity analysis to evaluate the impact of this assumption by estimating potential freshwater angler health risks under the alternative assumptions that these contaminants were not present in the fish tissue, and that they were present in concentrations equal to the detection limit.

Increasing the value used for nondetected contaminants from one-half the MDL to the MDL increases the species-weighted cancer risk by approximately 53 percent.[16] At typical consumption rates, the cancer risk never falls below 7.1×10^{-5}. The impact on cancer risks for consumption of individual species ranges from 95 percent for panfish to 19 percent for "other" species (see Appendix B). Risks for consuming catfish and "other" species always remain greater than 1×10^{-4}, and risks associated with bass consumption remain greater than 1×10^{-5}. Only the risks for consumption of trout and panfish fall into the 1×10^{-6} range when nondetects are set equal to zero.

Changing the value used for contaminants that were not detected above MDLs has a similar impact on estimated noncancer risks. The species-weighted HI changes by approximately 50 percent, resulting in a minimum HI of 1.2 and a maximum HI of 8.3 for typical consumption. At 90th percentile consumption, the HI ranges from a minimum of 5.9 to a maximum of 18.0. On a species-specific basis, the minimum HIs for trout and panfish fall below 1.0, while minimum HIs for bass, catfish, and "other" species remain greater than 1.0.

SAN FRANCISCO BAY ANGLERS

The second component of our analysis of health risks associated with exposure to fish tissue contaminants is a case study of San Francisco Bay anglers. The enclosed bays and estuaries that are addressed in the California Toxics Rule support diverse non-commercial fisheries that vary with respect to fishing activity, species composition, and contaminant levels. There is no one database or set of assumptions that can be applied across all of the anglers who fish in these waterbodies. Therefore, the impact of the rule on health risks for saltwater anglers must be considered on a site-specific basis. This case study provides a general indication of the potential risks faced by all anglers fishing in enclosed bays and estuaries. However, the case study only provides quantitative health risk estimates for the 125,000 recreational anglers fishing in San Francisco Bay; risks to the remaining 500,000 to 600,000 bay and estuary anglers throughout California are not calculated.[17]

---

[16] A corresponding 53 percent decrease in the species-weighted cancer risk occurs when the value used for nondetected contaminants decreases from one-half the MDL to 0.

[17] The estimate of 500,000 to 600,000 non-San Francisco Bay anglers is based on 3.6 million bay and estuary angler-days outside of San Francisco Bay and an average of 6.2 days per angler (see Chapter 4).

We selected San Francisco Bay for this case study because it represents one of the most significant non-commercial fisheries among the bays and estuaries covered by the rule. In addition, the Bay has been adversely affected by toxic water pollution, as evidenced by a health advisory issued in 1994 recommending against consumption of Bay sportfish more than twice a month. The advisory also recommends that adults should not eat any striped bass over 35 inches in length; and that sensitive populations (i.e., children under six years old and women who are pregnant, may become pregnant, or are breast feeding) should not eat more than one meal of sportfish per month and should not eat any large shark (over 24 inches) or large striped bass (over 27 inches).

While this advisory has been widely publicized, and pamphlets outlining these recommended restrictions are distributed with fishing licenses, extensive non-commercial fishing continues in the Bay. This case study estimates the potential individual and population risks faced by anglers consuming their catch, given the current level of toxics contamination in San Francisco Bay fish tissue.

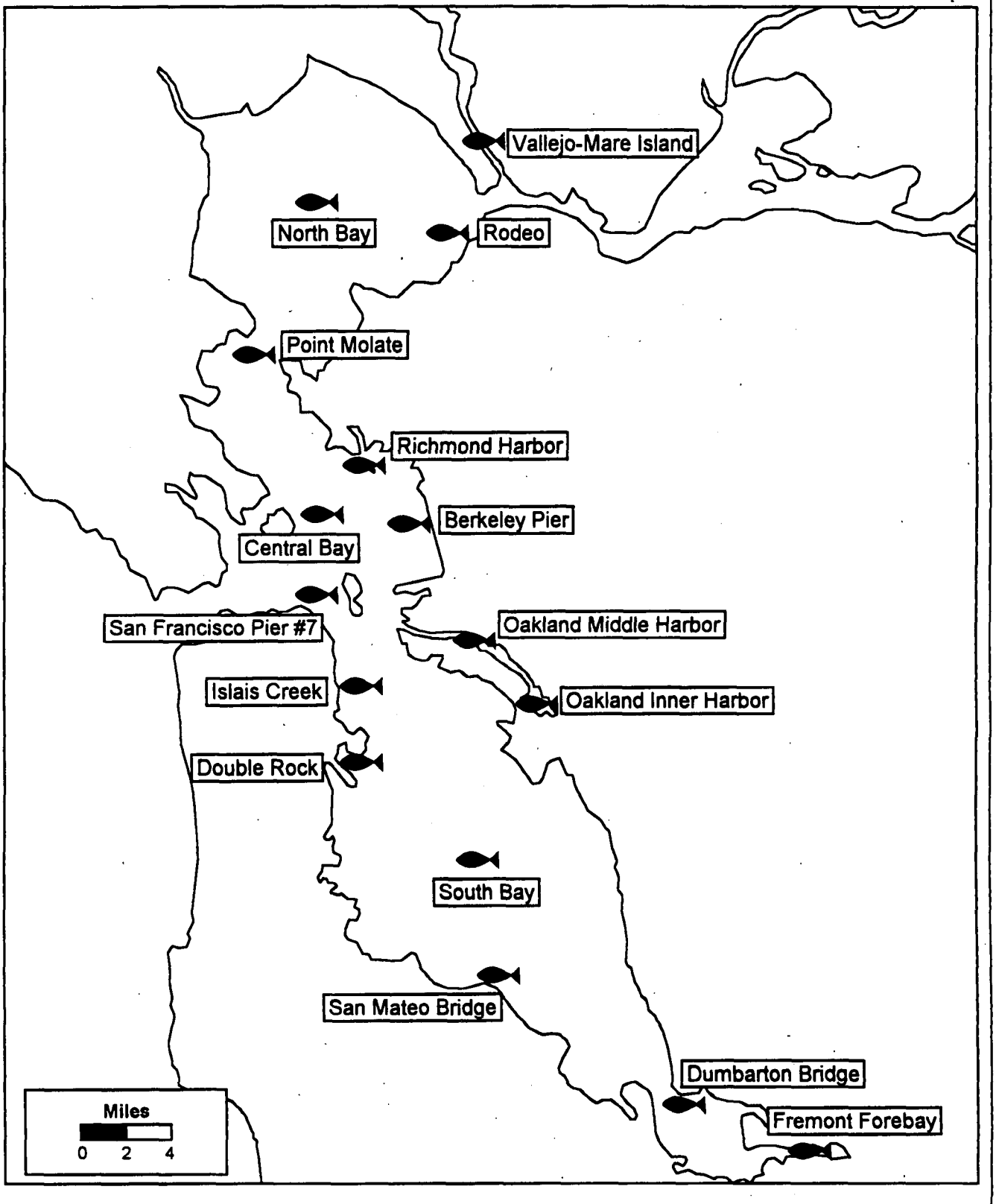
Fish Tissue Contaminant Levels

San Francisco Bay fish tissue contaminant levels were obtained from the San Francisco Regional Water Quality Control Board's 1994 study, *Contaminant Levels in Fish Tissue from San Francisco Bay*. This study includes fish tissue samples from 16 stations throughout the Bay. As shown in Exhibit 3-12, these sampling locations were selected to provide broad geographic coverage of the Bay. In addition, they were selected to include commonly fished shorelines and piers, areas of known contamination, and areas thought to be relatively contaminant free. Fish samples were collected at all of these areas in May and June 1994. Therefore, this database represents a snapshot of fish tissue contaminant levels throughout the Bay. Appendix B provides additional detail on the study's sampling design and protocol.

Our health risk analysis is based on fish tissue data for four species collected in the San Francisco Bay study: white croaker, striped bass, perch (shiner, walleye and white surf perch), and shark (brown smoothhound and leopard shark). A small number of halibut and sturgeon were also collected as part of this study; however, there were too few samples of these species to incorporate them into this analysis. In addition, jacksmelt was a targeted species in the San Francisco Bay study. Despite efforts to collect samples of this species, the investigators were unable to collect sufficient tissue samples to conduct chemical analyses.

Exhibit 3-12

SAN FRANCISCO BAY FISH SAMPLING LOCATIONS



The San Francisco Bay database contains concentration data for 19 contaminants covered by the California Toxics Rule, including both metals and organic compounds. Of these, 11 are classified by EPA as carcinogens and 17 are associated with noncarcinogenic effects. Exhibit 3-13 lists the weight of evidence for carcinogenicity, CSF, RfD, and specific target organs for each of these contaminants. These toxicity values were used in calculating the angler health risks associated with San Francisco Bay fish consumption.

For this analysis, we applied a CSF of 2.0 mg/kg-day for polychlorinated biphenyls (PCBs) based on EPA's revised October 1, 1996 guidance for assessment of carcinogenic human health risks associated with PCB exposure. EPA's revised guidance recommends a tiered approach that uses PCB CSFs ranging from 0.04 to 2.0 mg/kg-day depending on the characteristics of the exposure pathway and congener composition of the PCB mixture. EPA notes that bioaccumulated congeners ingested through the food chain (e.g., consumption of recreationally caught fish) tend to exhibit the highest chlorine content and persistence. Therefore, EPA recommends using the highest PCB CSF of 2.0 mg/kg-day for food chain exposure pathways where environmental processes tend to increase risk.[18]

The San Francisco Bay case study also follows EPA's recommendation to sum concentrations of individual PCB congeners (as opposed to Aroclor equivalents) in calculating Total PCBs.[19] The guidance further recommends that concentrations of PCB congeners exhibiting dioxin-like toxicity (often referred to as coplanar PCBs) be removed from PCB exposure estimates and added into estimates of 2,3,7,8-TCDD exposure using the Toxic Equivalence (TEQ) approach. This analysis, however, currently includes dioxin-like PCBs within the calculation of Total PCBs. This is done because the health risk analysis does not express 2,3,7,8-TCDD using the TEQ approach. Future revisions of this analysis will use the TEQ approach. As a result, the dioxin-like PCBs will be removed from the estimate of Total PCBs and added instead to the total concentration for 2,3,7,8-TCDD using Toxic Equivalent Factors (TEFs). TEFs will also be used to incorporate additional dioxin and furan congeners into the TEQ calculation of 2,3,7,8-TCDD. This will reduce the potential risks associated with PCBs while increasing risks associated with 2,3,7,8-TCDD.

---

[18] USEPA, National Center for Environmental Assessment, Office of Research and Development. *PCBs: Cancer Dose-Response Assessment and Application to Environmental Mixtures*, EPA/600/P-96/001F, September 1996.

[19] It was not possible to follow this convention in the freshwater analysis because the TSMP only measures PCBs as Aroclor equivalents. In the absence of congener concentrations, we relied on the Aroclor measurements in the calculation of Total PCBs in freshwater fish tissues.

Exhibit 3-13

TOXICITY VALUES FOR CONTAMINANTS IN SAN FRANCISCO BAY FISH TISSUE

Contaminant	CSF[1] $(mg/kg\text{-}day)^{-1}$	Cancer Weight[2] of Evidence	RfD[3] (mg/kg-day)	Target Organ
Cadmium	NA	D[4]	1.0×10^{-3}	Kidney
Copper	NA	D	3.7×10^{-2}	Gastro intestinal tract
Mercury	NA	C	1.0×10^{-4}	Central nervous system
Silver	NA	D	5.0×10^{-3}	Skin
Zinc	NA	D	3.0×10^{-1}	Blood
Chlordane	1.3	B2	6.0×10^{-5}	Liver
DDT[5]	0.34	B2	5.0×10^{-4}	Liver
Dioxin	1.50×10^{5}	B2	1.0×10^{-9}	Reproductive system
Dieldrin	16.0	B2	5.0×10^{-5}	Liver
HCH-alpha	6.3	B2	NA	NA
HCH-beta	1.8	C	NA	NA
HCH-gamma	1.3	B2-C	3.0×10^{-4}	Liver, kidney
Heptachlor	4.5	B2	5.0×10^{-4}	Liver
Heptachlor Epoxide	9.1	B2	1.3×10^{-5}	Liver
Hexachlorobenzene	1.6	B2	8.0×10^{-4}	Liver
Fluoranthene	NA	D	4.0×10^{-2}	Liver, kidney, blood
Fluorene	NA	D	4.0×10^{-2}	Blood
PCBs[6]	2.0	B2	2.0×10^{-5}	Immune system, reproductive system, liver, skin
Pyrene	NA	D	3.0×10^{-2}	Kidney

Source: Toxicity values obtained from USEPA's *Integrated Risk Information System* (4th Quarter, 1996) except for the copper and dioxin RfDs and the dioxin and HCH-gamma CSFs. Copper RfD and dioxin and HCH-gamma CSF values obtained from USEPA's *Health Effects Assessment Summary Table, 1994*. Dioxin RfD obtained from *Toxicological Profile for 2,3,7,8-Tetrachlorodibenzo-p-Dioxin*, Agency for Toxic Substances and Disease Registry, 1989.

1 Cancer Slope Factor
2 See Appendix D for definitions of weight of evidence.
3 Reference Dose
4 Classification for oral exposure only.
5 Toxicity values for DDT are based on 4,4'-DDT.
6 PCBs is calculated as the sum of the available congeners. The RfD for PCBs is based on Aroclor 1254.

Exposure Assumptions

Consumption Rate

The same fish consumption levels used to estimate exposure for freshwater anglers have been applied to Bay anglers. Specifically, individual risks were estimated based on typical consumption rates of 21.4 to 49.6 g/day. We calculated risks to individuals consuming larger amounts of fish using the 90th percentile consumption rate of 107.1 g/day. Population risks (for cancer effects only) were calculated using the typical fish consumption range, reflecting average consumption across the entire population.

As in the freshwater angler analysis, we estimated angler exposure in two ways. The first was based on the average contaminant concentrations for individual species to reflect the exposures of anglers who catch and consume a single species. The second was based on species-weighted average contaminant concentrations, reflecting the exposure of anglers who catch and consume a variety of species.

As shown in Exhibit 3-14, species-weighted contaminant concentrations were based on catch rates in San Francisco Bay reported by the National Marine Fisheries Service (NMFS).[20] White croaker is the most frequently caught species, representing 43 percent of the catch. It is followed by surf perch, striped bass and shark at 35 percent, 14 percent and eight percent of the catch, respectively.[21] Keep rates for these species were not available. Therefore, we use catch rates alone to develop overall species weights. As a result, we assume that anglers keep and eat fish in the same proportions that the recreational catch occurs. Any difference in keep rates across species would alter the species weights. The potential impact of this uncertainty is explored later in this section.

---

[20] National Marine Fisheries Service, *National Marine Recreational Fishery Statistics Survey, Pacific Coast*, 1987-1989 and 1993.

[21] Jacksmelt were the second most frequently caught fish species in San Francisco Bay; however, we have excluded this species from this analysis due to a lack of contaminant data.

Exhibit 3-14

SPECIES WEIGHTS FOR SAN FRANCISCO BAY FISH CONSUMPTION

Species[1]	Number of Fish Caught	Percent of Catch
White croaker	532	43.1 %
Surf perch[2]	432	35.0 %
Striped bass	171	13.9 %
Shark[3]	99	8.0 %
Total	1,234	100 %

Source: National Marine Fisheries Service Marine Recreational Fishing Statistics Survey, Pacific Coast, 1987-1989 and 1993.

1 Jacksmelt was the second most frequently caught species (435 fish). This species was excluded from calculations of species weights because no tissue contaminant data were available.

2 Includes shiner, walleye, pile, black and rubberlip surf perch.

3 Includes brown, smoothhound, and leopard shark.

Angler Population

In estimating the angler population for this case study, we focused on people living in the eight counties in the immediate San Francisco Bay area. These counties include Alameda, Contra Costa, Marin, San Francisco, San Mateo, Santa Clara, Solano and Sonoma. Statistics reported in a survey of fishing activity in Central and Northern California conducted by NMFS support this approach.[22] Coastal county residents account for more than 95 percent of saltwater fishing activity in seven counties that abut San Francisco Bay for which the survey reported fishing participation by area of residence.[23]

---

[22] National Marine Fisheries Service, *Results of the Bay Area Sportfish Economic Study*, NOAA-TM-NMFS-SWFC-78, August 1987.

[23] The survey included fishing in San Francisco Bay and in the Pacific Ocean in all of the counties surrounding the Bay, except for Santa Clara. The percentage of fishing activity attributable to coastal county residents was assumed to be equal for both bay and ocean fishing.

According to NMFS' survey, there are approximately 332,000 saltwater anglers living in the eight counties that abut San Francisco Bay. Fishing activity among these anglers is split in two ways. First, San Francisco Bay anglers may fish exclusively in the Bay or the ocean, while others may fish in both areas. Second, these anglers may limit their fishing activity to saltwater, or they may fish in both salt and freshwater. These variations in fishing habits among San Francisco Bay anglers have implications for estimating the individual and population exposure levels to fish tissue contaminants. At the individual level, anglers fishing exclusively in the Bay will have higher exposures to any contaminants present in Bay fish than anglers who spend a portion of their time fishing either in the ocean or freshwater. For purposes of this analysis, we have focused on the individual risks for anglers who limit their fishing activity to the Bay.

To estimate population exposure levels, though, it is important to consider the impact of differing fishing habits on the average exposure across the population of anglers. As noted earlier, the average exposure level is particularly relevant when estimating the population cancer risk. Therefore it is necessary to adjust the angler population to reflect this range of fishing habits. NMFS' survey of Central and Northern California fishing activity provides a means of estimating the proportion of saltwater fishing activity that occurs in the Bay. Roughly 50 percent of the saltwater fishing trips over a geographic area that includes the Pacific Coast from north of Stimson Beach to south of Davenport, as well as the Bay itself, occur in the Bay. This estimate incorporates fishing activity by all modes, including beach, pier, private boat, and party/charter boat.

The F&WS *1991 National Survey of Fishing, Hunting and Wildlife-Associated Recreation* provides a means of estimating the proportion of anglers who fish exclusively in saltwater. According to this survey, 50 percent of the saltwater anglers in California fish exclusively in saltwater, while the remaining saltwater anglers split their fishing activity between salt and freshwater. In the absence of data on the relative level of effort devoted to fresh and saltwater fishing among these anglers, we have assumed that activity is evenly split between these two types of fishing.

Combining the information from these two surveys, we adjusted the Bay angler population to reflect the number of full-time equivalent anglers. Starting with the original estimate of 332,000 Bay anglers, we reduce the figure by half to account for saltwater fishing activity outside of the Bay. This number is then further reduced by 25 percent to reflect that 50 percent of the Bay anglers split their fishing activity evenly between fresh and saltwater. Thus, the full-time equivalent estimate of Bay anglers is approximately 125,000.

Potential Angler Health Risks

Potential cancer risks associated with exposure to all 11 carcinogenic contaminants at concentrations currently found in San Francisco Bay fish are presented in Exhibit 3-15. The total incremental excess lifetime cancer risk (ILCR) for typical anglers consuming a mixed species diet ranges from 1.8×10^{-4} to 4.3×10^{-4}. For anglers consuming a mixed species fish diet at the 90th percentile consumption levels, the ILCR is 9.2×10^{-4}. Based on typical consumption rates and an angler population of approximately 125,000, we expect these contaminants to result in less than one to one case of cancer per year; over 70 years, we expect between 23 and 53 excess cases of cancer. These risks are dominated by PCBs and dioxin, which contribute roughly 49 and 41 percent of the cancer risk, respectively. PCBs have an ILCR ranging from 9.0×10^{-5} to 2.1×10^{-4} for typical consumption. Dioxin has an ILCR ranging from 7.6×10^{-5} to 1.8×10^{-4} under typical consumption.

Exhibit 3-15

POTENTIAL BASELINE CANCER RISK FOR RECREATIONAL ANGLERS CONSUMING SAN FRANCISCO BAY FISH

Contaminant	Individual Excess Lifetime Cancer Risk: Typical Consumption (21.4 - 49.6 g/day)	Individual Excess Lifetime Cancer Risk: 90th Percentile Consumption (107.1 g/day)	Population Cancer Risk[1] (excess cases per year)	Relative Contribution
PCBs	9.0×10^{-5} - 2.1×10^{-4}	4.5×10^{-4}	<1 - <1	49.0 %
Dioxin	7.6×10^{-5} - 1.8×10^{-4}	3.8×10^{-4}	<1 - <1	41.2 %
Dieldrin	7.8×10^{-6} - 1.8×10^{-5}	3.9×10^{-5}	0	4.2 %
DDT	4.9×10^{-6} - 1.1×10^{-5}	2.4×10^{-5}	0	2.6 %
Chlordane	3.9×10^{-6} - 9.1×10^{-6}	2.0×10^{-5}	0	2.1 %
HCH-alpha	4.8×10^{-7} - 1.1×10^{-6}	2.4×10^{-6}	0	0.3 %
Heptachlor Epoxide	3.8×10^{-7} - 8.8×10^{-7}	1.9×10^{-6}	0	0.2 %
HCH-beta	1.7×10^{-7} - 3.9×10^{-7}	8.5×10^{-7}	0	0.1 %
Heptachlor	1.6×10^{-7} - 3.6×10^{-7}	7.7×10^{-7}	0	0.1 %
HCH-gamma	9.2×10^{-8} - 2.1×10^{-7}	4.6×10^{-7}	0	<0.1 %
Hexachlorobenzene	8.1×10^{-8} - 1.9×10^{-7}	4.1×10^{-7}	0	<0.1 %
Total	**1.8×10^{-4} - 4.3×10^{-4}**	**9.2×10^{-4}**	**<1 - 1**	**100 %**

[1] Based on typical fish consumption (21.4 to 49.6 g/day) and a San Francisco angler population of 125,000. Values rounded to the nearest cancer case.

Noncancer risks for Bay anglers are summarized in Exhibit 3-16. At the typical consumption rate, HI values range from 3.6 to 8.4. At the 90th percentile consumption rate, the HI is 18.1. PCBs dominate these risks, accounting for 62 percent of the HI. The HQ for PCBs ranges from 2.3 to 5.2 for typical anglers; the HQ increases to 11.3 at the 90th percentile level. Mercury accounts for approximately 21 percent of the noncancer risk. At typical consumption rates, mercury's HQ ranges from 0.8 to 1.7; at 90th percentile consumption, mercury's HQ is 3.8. Dioxin, which accounts for 14 percent of the HI, is the only other contaminant that has an HQ as high as 1.0; dioxin's HQ ranges from 0.51 to 1.17 at typical consumption rates. These results suggest that PCBs, mercury, and dioxin are the contaminants with the greatest potential to cause adverse health effects for Bay anglers. The specific noncancer effects associated with all of these contaminants are listed above in Exhibit 3-13 and described in Appendix D.

Exhibit 3-16

POTENTIAL BASELINE NONCANCER RISK FOR RECREATIONAL ANGLERS CONSUMING SAN FRANCISCO BAY FISH

Contaminant	Hazard Quotient		Relative Contribution
	Typical Consumption (21.4 - 49.6 g/day)	90th Percentile Consumption (107.1 g/day)	
PCBs	2.26 - 5.24	11.31	62.4 %
Mercury	0.75 - 1.74	3.77	20.8 %
Dioxin	0.51 - 1.17	2.54	14.0 %
Chlordane	0.05 - 0.12	0.25	1.4 %
DDT	0.03 - 0.07	0.14	0.8 %
Dieldrin	0.01 - 0.02	0.05	0.3 %
Zinc	0.01 - 0.02	0.04	0.2 %
Heptachlor Epoxide	<0.01 - 0.01	0.02	0.1 %
Copper	<0.01 - 0.01	0.01	0.1 %
Cadmium	<0.01 - <0.01	<0.01	<0.1 %
HCH-gamma	<0.01 - <0.01	<0.01	<0.1 %
Silver	<0.01 - <0.01	<0.01	<0.1 %
Heptachlor	<0.01 - <0.01	<0.01	<0.1 %
Hexachlorobenzene	<0.01 - <0.01	<0.01	<0.1 %
Fluoranthene	<0.01 - <0.01	<0.01	<0.1 %
Pyrene	<0.01 - <0.01	<0.01	<0.1 %
Fluorene	<0.01 - <0.01	<0.01	<0.1 %
Hazard Index	**3.62 - 8.39**	**18.13**	**100 %**

To ensure that anglers who catch and consume a single species are not subject to higher risk levels than those consuming mixed species diets, we estimated health risks based on mean contaminant concentrations for each of the four San Francisco Bay species groups. As shown in Exhibit 3-17, a fish diet consisting of white croaker poses the highest cancer risk. Based on typical consumption patterns, the excess risk associated with a diet of white croaker ranges from 2.9×10^{-4} to 6.7×10^{-4}, approximately 1.6 times higher than the species-weighted risk. Shark pose the lowest risk with an ILCR ranging from 3.7×10^{-5} to 8.6×10^{-5}. Although this is approximately five times less than the species-weighted risk, shark still pose risk at the 1×10^{-5} level.

Exhibit 3-17

POTENTIAL BASELINE HEALTH RISKS ASSOCIATED WITH CONSUMPTION OF DIFFERENT SAN FRANCISCO BAY SPECIES

	Individual Excess Lifetime Cancer Risk		Noncancer Risk (Hazard Index)	
Species	Typical Consumption (21.4 - 49.6 g/day)	90th Percentile Consumption (107.1 g/day)	Typical Consumption (21.4 - 49.6 g/day)	90th Percentile Consumption (107.1 g/day)
White croaker	2.9×10^{-4} - 6.7×10^{-4}	1.4×10^{-3}	5.1 - 11.8	25.5
Striped bass	1.6×10^{-4} - 3.7×10^{-4}	8.0×10^{-4}	3.0 - 7.0	15.1
Surf perch	1.2×10^{-4} - 2.8×10^{-4}	6.0×10^{-4}	2.3 - 5.4	11.6
Shark	3.7×10^{-5} - 8.6×10^{-5}	1.9×10^{-4}	2.7 - 6.3	13.6
Species-Weighted Value	1.8×10^{-4} - 4.3×10^{-4}	9.2×10^{-4}	3.6 - 8.4	18.1

Noncancer risks for single species also are comparable to the risk associated with a mixed species diet. White croaker produce the highest HI of 5.1 to 11.8 at the typical consumption level, 1.4 times higher than the species-weighted HI. Surf perch pose the lowest noncancer risk, an HI of 2.3 to 5.4, only about 1.6 times less than the species-weighted HI. Note that each individual species poses substantial noncancer health risks, as all species have HIs greater than 2.0 at the low end of the typical consumption range.

Uncertainties

The methodology used to estimate health risks for Bay anglers includes a series of assumptions that are a source of uncertainty in the results of this analysis. Some of these assumptions apply to the analyses of both freshwater and Bay anglers, while others are specific to the Bay angler analysis. The uncertainties related to assumptions made in the following two elements of the Bay angler analysis are described below:

- Deriving species weights that reflect the relative contribution of individual species to the Bay angler fish diet; and
- Assigning concentration values to contaminants for samples in which they were not detected above the MDL.

Additional uncertainties that are relevant to both the freshwater and Bay angler analyses are discussed in a later section of this chapter.

Species Weights

The relative contribution of individual species to Bay anglers' diets is based on catch rates from NMFS fishing surveys conducted in San Francisco Bay from 1987 to 1989 and in 1993. By relying on catch rates to develop species weights, we assume that keep rates are comparable across the four species in our analysis: shark, striped bass, surf perch, and white croaker. Given that there is relatively little variation in the health risks associated with contaminant levels in these different species, any change in the species weights due to differences in keep rates would have little impact on the health risk estimates. Based on the range of risk estimates across the four species presented in Exhibit 3-17, any change in the species weights could increase or decrease the species-weighted risk by a factor of roughly 1.4 to 4.9. In all cases, potential health risks remain significant.

An additional source of uncertainty in the species weights for Bay anglers' diets is the exclusion of jacksmelt from the analysis. According to the NMFS fishing surveys, jacksmelt is the second most frequently caught fish in the Bay. However, we could not evaluate the potential risk associated with consuming jacksmelt because no fish tissue contaminant data were available for this species. The relatively small degree of variation in risks associated with consuming the four species that were included in the analysis suggests that the lack of contaminant data on jacksmelt is unlikely to significantly over- or underestimate Bay angler risks.

Contaminants Not Detected Above MDLs

As noted previously, in calculating the average fish tissue concentrations used to estimate health risks for anglers, we assume that all contaminants not detected in specific fish tissue samples above MDLs are present at concentrations equal to one-half of the MDL. To test the impact of this assumption on the analysis of Bay angler health risks, we estimated Bay angler health risks under two alternative assumptions. First, we set the concentration of nondetected contaminants in these fish tissue samples to zero. Second, we set nondetect concentrations equal to the MDL.

The results of these analyses show that changing the concentration assigned to nondetected values from one-half the MDL to either zero or the MDL has little effect on the estimated risks for anglers. Cancer risk levels change by approximately 16 percent under the alternative assumptions and do not fall below 1×10^{-4}. Noncancer risks change by no more than six percent and the hazard index remains above 3.0. The low variation across alternate MDL assumptions mainly results from the stringency of the detection limits applied in the San Francisco Bay study and the corresponding high frequency of detection.

UNCERTAINTIES

As noted above, the methodology used to estimate health risks for freshwater and San Francisco Bay anglers includes a series of assumptions that are a source of uncertainty in the results of this analysis. We have discussed many of these assumptions and their potential impacts on either the freshwater or Bay angler results in previous sections of this chapter. In this section, we focus on additional uncertainties that affect both of these analyses.

Risks to Family Members

This analysis focuses solely on risks associated with anglers' consumption of fish containing toxic contaminants. It does not address the potential risks that anglers' families may face by sharing in consumption of their catch. A study of San Francisco Bay anglers fishing from public piers suggests that the impact of this assumption on the estimated health risks associated with Bay area fishing could be significant. Approximately 45 percent of the anglers surveyed shared some portion

of their catch with family members.[24] Although quantitative estimates are not available, anglers that share their catch are likely to keep more fish than anglers who do not share their catch. As a result, each family member could be exposed at typical consumption rates (adjusted for age and body weight). Therefore, we may understate the size of the population exposed to toxic contaminants in non-commercially caught fish, as well as the resulting population risk.[25] In addition, family members with increased exposure on a body weight basis or increased sensitivity to exposure, such as young children or women who are pregnant or breast feeding, may face higher risks than those estimated for anglers.

Cooking

Freshwater and Bay angler risk estimates were based on tissue contaminant levels measured in raw fish fillets. The data reported for raw tissue may overstate angler exposure due to reductions in contaminant levels during cooking. Studies have shown that virtually all methods of cooking fish can lead to reductions in contaminant levels. In its study of marine fish contamination in Southern California, OEHHA noted that PCB and DDT concentrations decrease by 20 percent to 80 percent after cooking.[26] A recently published study of cooking-related reductions in dioxin concentrations in Great Lakes fish suggests that many cooking methods produce significant reductions in dioxin

---

[24] See Save San Francisco Bay Association's, *Eating Seafood from San Francisco Bay: a Report on Fishing and Consumption Patterns, and a Review of Government Monitoring and Assessment of Health Risk from Contaminants in the Bay, Draft,* April 1995. No comparable data were available for freshwater anglers; however, it is likely that a proportion of these anglers also share their catch with family members.

[25] The fish consumption values used to assess individual and population angler health risks are estimates of consumption by only the anglers. No consumption by family members is reflected in these values. Any consumption of an angler's catch by family members would represent consumption of additional fish over and above the values used for angler consumption in this analysis.

[26] California OEHHA, *A Study of Chemical Contamination of Marine Fish from Southern California II: Comprehensive Study,* 1991.

concentrations. Baking, charbroiling, pan frying and deep fat frying all resulted in dioxin reductions of roughly 50 percent. Reductions of PCB and pesticide levels after cooking averaged roughly 33 percent.[27]

Although cooking-related reductions in contaminant levels can range from 20 percent to 80 percent, this uncertainty does not significantly alter estimated angler health risks. First, potential reductions are highly variable across contaminants and cooking methods. Second, even if we assume the maximum possible reduction of 80 percent for all contaminants, potential individual risks for anglers generally remain high. Under this scenario, cancer risks for freshwater and San Francisco Bay anglers remain approximately 3.0×10^{-5} to 8.0×10^{-5} in the typical consumption range. The noncancer hazard indices for typical consumption rates remain approximately 0.5 to 1.1 for freshwater anglers and 0.7 to 1.7 for San Francisco Bay anglers.

Arsenic

EPA classifies inorganic forms of arsenic (e.g., arsenite and pentavalent arsenic) as human carcinogens through oral exposure. In almost all cases, however, arsenic in edible fish tissues is present as arsenic-containing organic compounds.[28] These organic forms of arsenic are much less toxic than the inorganic forms and generally are not considered a threat to human health.[29] Both the San Francisco Bay study and the TSMP measured arsenic in fish tissues. In the San Francisco Bay study, arsenic was detected in all of the composites at a mean concentration of 1.1 parts per million. Shark had the highest mean concentration of any Bay area species at 3.2 parts per million. The TSMP measured arsenic in approximately one-half of the composites tested for the compound at a mean concentration of 0.9 parts per million.

---

[27] Zabik, M.E and M.J. Zabik. "Tetrachlorodibenzo-p-dioxin Residue Reduction by Cooking/Processing of Fish Fillets Harvested from the Great Lakes," Bulletin of Environmental Contamination and Toxicology. V.55, 1995, pp. 264-269.

[28] National Academy of Sciences, *Seafood Safety*. Committee on Evaluation of the Safety of Fishing Products, National Academy Press, Washington D.C., 1991.

[29] USEPA, *Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories: Volume 1, Fish Sampling and Analysis*, Office of Water, EPA 823-R-93-002, August 1993.

Tissue samples from the San Francisco Bay study were dominated by the organic forms of arsenic (organoarsenical and arsenobetaine); the TSMP does not provide information on the form of arsenic measured in its fish tissues. Similarly, neither study attempted to calculate organic to inorganic arsenic ratios. Therefore, since the available evidence indicates that organic arsenic dominates California fish tissues, we do not calculate potential cancer or noncancer health risks associated with arsenic exposure. However, to the extent that small amounts of inorganic forms of arsenic are present in edible fish tissues, the analysis will understate potential angler health risks.

ENVIRONMENTAL JUSTICE

Executive Order 12898 requires all federal agencies to identify and address as appropriate the potential impact of proposed regulations on minority and low-income populations within the community. In keeping with this Executive Order we have examined the potential for minority and low-income anglers to face greater health risks from exposure to current levels of toxics in fish tissue. The potential for minority and low-income anglers to face higher risk levels arises from differences in their fish consumption patterns relative to the overall population of anglers, including differences in the amount of fish consumed and in fish preparation methods.

Fish Consumption Rates

According to the results of the Santa Monica Bay study, differences in consumption rates between the general California angler population and minority and low-income anglers are generally small; neither the typical nor the 90th percentile consumption rates selected for this analysis significantly understate potential risks for these anglers. There was little difference in the median consumption rates reported across White, Hispanic, Black and Asian anglers. Values ranged from 16.1 g/day to 24.1 g/day, very close to the 21.4 g/day median value used in this analysis. There was more variation in the 90th percentile consumption rates across ethnic groups. These high level consumption rates were lowest for Hispanic and Black anglers, 64.3 g/day and 85.7 g/day, respectively. Rates for White and Asian anglers were considerably higher, at 112.5 g/day and 115.7 g/day, respectively. These higher rates, however, are only slightly higher or lower than the 90th percentile value of 107.1 g/day used in this analysis.

Results reported for anglers of "other" ethnic descent do suggest the potential for higher consumption rates for some California ethnic groups. Values reported for the 14 Middle Eastern, Samoan and Cambodian anglers included in this ethnic category were 85.7 g/day and 173.6 g/day

at the median and 90th percentile levels, respectively. Although these rates are four and 1.6 times higher than those used in this analysis, the small sample of anglers on which they are based makes it difficult to evaluate the representativeness of these consumption rates.

The Santa Monica Bay study also reported only minor differences in fish consumption rates across income levels. The median consumption rate for the lowest income anglers in this study (less than $5,000) was 32.1 g/day; while the consumption rate for all anglers with incomes above $5,000 was 21.4 g/day. The 90th percentile consumption rates for different income levels range from 64.3 g/day to 128.6 g/day, with high income anglers having the highest rate. Thus, neither the typical nor the 90th percentile consumption rates used in this analysis significantly understate consumption rates for low-income anglers.

In a 1988 study, Lance *et al.* surveyed low income mothers enrolled in Los Angeles County's Women, Infants, and Children program to evaluate fresh fish consumption and breast milk contaminants.[30] Out of the 45 participants in the breast milk study, 35 ate fresh fish obtained from local markets or recreational/subsistence angling. More than fourteen percent of the fish eaters obtained fish directly from a family member or local angler. Study participants ate an average of 4.2 fish meals per month. Other mothers that were not eligible or refused to participate in the breast milk study ate approximately 4.8 fish meals per month.

Using a fish fillet model, Lance *et al.* found that half of the fish eaters in the study ate approximately 150 grams of fish per meal, while the other half ate more than 150 grams per meal. Therefore, assuming 4.2 meals per month and 150 grams per meal, these low-income mothers ate approximately 21 grams of fish per day. Since these are both lower bounds, the consumption rates used in this study do not appear to significantly over- or under-estimate fish consumption for low-income anglers.

Contrary to the Santa Monica Bay study and Lance *et al.* income findings, EPA has reported higher consumption rates for low-income, minority and subsistence anglers in other studies. In the *Regulatory Impact Analysis of the Final Great Lakes Water Quality Guidance*, EPA cites a 1993 study of Michigan anglers by West that reports a consumption rate of 43.1 g/day for low-income

---

[30] Lance, L., Papanek, P., Ward, C., and Peterson, J. *Breast Milk Contaminants and Fresh Fish Consumption in Southern California: Results of a Pilot Survey.* DRAFT. Prepared by the Department of Health Services, County of Los Angeles, 1988.

minority anglers.[31] In its draft report to Congress on mercury, EPA cites median and 90th percentile consumption rates for subsistence anglers of 30 g/day and 170 g/day, respectively.[32] A comparison of these rates to those used in this analysis suggests that we may understate risks for low-income, minority, and subsistence anglers by a factor of 1.4 at the median level and a factor of 1.6 at the 90th percentile level.

Currently, EPA's Region 9 office is designing a study in conjunction with local community networks to provide more accurate estimates of fish consumption rates in California's Asian and subsistence fishing populations.[33] The study, which will be finalized sometime in 1998, will provide complete fishing activity profiles for many of California's ethnic populations. At that time, we will be able to provide quantitative determinations about whether members of specific ethnic groups face disproportionate health risks as a result of consuming local fish and shellfish.

Fish Preparation Methods

Differences in preparation and cooking techniques represent another way in which risks could vary across subgroups of the general population. Many of the toxic contaminants evaluated in this analysis (including PCBs, which represent the most significant source of human health risk) accumulate in fatty tissue and internal organs of fish. Therefore, anglers who consume whole fish or untrimmed fillets (i.e., including the skin) face higher risks than those consuming only trimmed fillets. For example, trimming the fat and skin may remove approximately 45 percent of the PCBs in a standard fillet.[34]

---

[31] USEPA, *Regulatory Impact Analysis of the Final Great Lakes Water Quality Guidance, Final Report,* Office of Science and Technology, March 1995.

[32] USEPA, *Mercury Study Report to Congress, Volume VI: Characterization of Human Health and Wildlife Risks from anthropogenic Mercury Emissions in the United States, Draft,* Office of Air Quality Planning and Standards and Office of Research and Development, December 12, 1994.

[33] Arthur Den (USEPA) and Audry Chiang (Asian Pacific Environmental Network), personal communication, October 7, 1996.

[34] Voiland, MP ,DL Gall, DJ Lisk, and DB MacNeill, "Effectiveness of Recommended Fat-Trimming Procedures on the Reduction of PCB and Mirex Levels in Brown Trout from Lake Ontario," *Journal of Great Lakes Research*, volume 17, number 4, pages 454-460, 1991.

eat fish whole, but gutted, including nearly 50 percent of Asians and 44 percent of Hispanics. The freshwater angler analysis understates risks for these anglers because freshwater fish tissue contaminant data are based on chemical analysis of fillets without skin. The San Francisco Bay angler risk estimates, however, do not significantly understate risks for these anglers because Bay fish tissue samples were prepared for chemical analysis according to the most frequent means of consumption (i.e., white croaker and surf perch fillets were analyzed with skin, and shark and striped bass were analyzed without skin).

POTENTIAL HEALTH BENEFITS TO RECREATIONAL ANGLERS ASSOCIATED WITH IMPLEMENTATION OF THE CALIFORNIA TOXICS RULE

Reducing loadings of toxic chemicals to California's waters to meet the ambient water quality criteria prescribed by the California Toxics Rule has the potential to result in corresponding reductions in fish tissue contaminant levels. The magnitude of these reductions, however, depends on implementation of the rule and complex interactions among future pollutant loadings, historic contamination (including sediment contamination), site-specific ecological and geologic characteristics, and chemical absorption and bioaccumulation in fish tissues. Based on the potential post-rule contaminant reductions in water and fish tissues, we estimated the potential human health benefits associated with achieving criteria under the CTR.

Because of the uncertainty in determining post-rule conditions, we estimate potential benefits under two scenarios.

Scenario 1: The first benefit scenario assumes the water quality criteria in the proposed rule (which for human health criteria for carcinogens are based on a 1×10^{-6} risk level for the general population) are attained. While the criteria would apply to all waters specified in the rule, the Clean Water Act provides regulatory authority only for point sources (nonpoint source controls are either voluntary or come from state law). Where there are nonpoint sources contributing discharges, point source controls may only reduce a portion of the overall discharges to the waterbody. Thus, this approach yields an upper bound of the rule's human health benefits. (See Chapter 7 for the apportionment of health benefits associated with point source controls).

Scenario 2: The second benefit scenario assumes the water quality criteria in the proposed rule are attained using a 1×10^{-5} risk level for the general population. This approach yields a lower bound of the rule's human health benefits.

Cancer Risk Benefits to Recreational Anglers

Calculation of Post-Rule Fish Tissue Contaminant Concentrations

We calculated the potential risk reductions associated with implementation of the California Toxics Rule by comparing baseline health risks with estimated post-rule risks. For the purposes of this analysis, post-rule conditions are defined as the fish tissue concentrations associated with a human health criteria based on the 1×10^{-6} and 1×10^{-5} risk levels. We calculate the post-rule fish tissue levels and resulting health risks based on the same exposure assumptions and risk analysis equations used to calculate potential baseline risks.

The analysis of freshwater and San Francisco Bay health benefits focuses on six contaminants representing 98 percent or more of the quantified/monetized risk for freshwater and San Francisco Bay anglers. To calculate post-rule fish tissue concentrations, we first identified the most stringent criteria for each compound (i.e., the chronic aquatic life criteria or the human health criteria). For five of the contaminants (chlordane, DDT, dieldrin, dioxin, and PCBs), the rule's proposed human health criteria for consumption of aquatic organisms are the most stringent.

The CTR's target risk level of 1×10^{-6} is based on a 6.5 gram per day consumption rate for the general population. As a result, the CTR protects the general population at the rule's target risk level. Scenario 1 recognizes that recreational and subsistence anglers consume fish at higher rates than the general population. Therefore, we substitute the consumption estimates used in this analysis into the exposure equations. This results in estimated post-rule fish tissue concentrations that are higher than those derived using 6.5 grams per day consumption. We then use the cancer slope factors for each contaminant to estimate post-rule risks. Since these estimates are based on consumption of 21.4 to 49.6 grams per day, the resulting estimates of post-rule individual risks for these contaminants range from 3.3×10^{-6} to 7.6×10^{-6}.

We follow the same procedure to calculate post-rule fish tissue concentrations and risks under Scenario 2. Under this scenario, however, we calculated post-rule risks associated with human health criteria based on a target risk level of 1×10^{-5}. Again, we derived the post-rule fish tissue concentrations and estimates of health risks based on the higher consumption rates used in the

baseline analysis. Under Scenario 2, the calculated risk levels for chlordane, DDT, and dieldrin would be higher than baseline risks; as a result, there is no change in risk as a result of the rule's implementation. For PCBs and dioxin, the individual post-rule cancer risk for criteria based on the 1×10^{-5} risk level for the general population ranges from 3.3×10^{-5} to 7.6×10^{-6}.

We applied a modified approach to determine the post-rule cancer risks associated with toxaphene. The aquatic life criterion for toxaphene is nearly four times more stringent than the human health criterion. Thus, the post-rule individual risk levels for this contaminant range from 8.8×10^{-7} to 2.0×10^{-6} for the typical fish consumption rate.

Freshwater Cancer Benefits to Recreational Anglers

The potential health benefits associated with full implementation of the CTR's proposed water quality criteria are presented in Exhibit 3-18. Assuming criteria based on a risk level of 1×10^{-6} for the general population, potential cancer risks for freshwater anglers decrease by 91 percent when the water quality criteria established by the CTR are met. Baseline population cancer risks resulted in 5 to 11 cancer cases per year among freshwater anglers; once implemented, the rule has the potential to reduce this to between zero and one case per year. Baseline individual excess lifetime cancer risks range between 1.5×10^{-4} and 3.5×10^{-4} for typical anglers. Post-rule risks for individual contaminants range from 70 to 97 percent below baseline estimates. The largest reductions are associated with toxaphene (97 percent) and PCBs (94 percent).

Under Scenario 2, criteria based on a risk level of 1×10^{-5} for the general population, the total potential reduction in cancer risks is 37 percent. The resulting number of annual cancer cases is between three and seven for typical consumption. Baseline risks for chlordane, DDT, and dieldrin already meet the 1×10^{-5} risk level, and consequently have no post-rule benefits. Post-rule risks for toxaphene and PCBs, however, are 97 and 41 percent lower than baseline, respectively.

San Francisco Bay Cancer Benefits to Recreational Anglers

The results of the San Francisco Bay benefits analysis for carcinogenic effects are presented in Exhibit 3-19. Assuming criteria based on a protection standard of 1×10^{-6} for the general population, cancer risks for these anglers decrease by 91 percent post-rule. Baseline population cancer risks resulted in less than one to one cancer case per year among San Francisco Bay anglers (approximately 23 to 53 cases for the population over 70 years). Achieving the CTR's water quality

Exhibit 3-18

POTENTIAL FRESHWATER CANCER HEALTH BENEFITS TO RECREATIONAL ANGLERS UNDER THE CALIFORNIA TOXICS RULE: ESTIMATED POST-RULE FRESHWATER ANGLER RISKS AND PERCENT REDUCTION RELATIVE TO BASELINE[1]

			Post-rule					
	Baseline		Achieve Post-rule Criteria Based on Risk Level of 1×10^{-6} for the General Population			Achieve Post-rule Criteria Based on Risk Level of 1×10^{-5} for the General Population		
Contaminant	Individual Excess Lifetime Cancer Risk (21.4 - 49.6 g/day)	Population Cancer Risk (excess cases per year)	Individual Excess Lifetime Cancer Risk (21.4 - 49.6 g/day)	Population Cancer Risk (excess cases per year)	Percent Reduction	Individual Excess Lifetime Cancer Risk (21.4 - 49.6 g/day)	Population Cancer Risk (excess cases per year)	Percent Reduction
Chlordane[2]	1.1×10^{-5} - 2.5×10^{-5}	<1 - 1	3.3×10^{-6} - 7.6×10^{-6}	<1 - <1	70 %	1.1×10^{-5} - 2.5×10^{-5}	<1 - 1	0 %
DDT[2]	2.5×10^{-5} - 5.8×10^{-5}	1 - 2	3.3×10^{-6} - 7.6×10^{-6}	<1 - <1	87 %	2.5×10^{-5} - 5.8×10^{-5}	1 - 2	0 %
Dieldrin[2]	2.4×10^{-5} - 5.6×10^{-5}	1 - 2	3.3×10^{-6} - 7.6×10^{-6}	<1 - <1	86 %	2.4×10^{-5} - 5.6×10^{-5}	1 - 2	0 %
PCBs[2]	5.6×10^{-5} - 1.3×10^{-4}	2 - 4	3.3×10^{-6} - 7.6×10^{-6}	<1 - <1	94 %	3.3×10^{-5} - 7.6×10^{-5}	1 - 2	41 %
Toxaphene[3]	3.2×10^{-5} - 7.5×10^{-5}	1 - 2	8.8×10^{-7} - 2.0×10^{-6}	<1 - <1	97 %	8.8×10^{-7} - 2.0×10^{-6}	<1 - <1	97 %
Total	**1.5×10^{-4} - 3.5×10^{-4}**	**5 - 11**	**1.4×10^{-5} - 3.3×10^{-5}**	**0 - 1**	**91 %**	**9.4×10^{-5} - 2.2×10^{-4}**	**3 - 7**	**37 %**

1 Cancer risks associated with the contaminants listed in this exhibit represent 98 percent of the total estimated cancer risk for freshwater anglers.

2 Post-rule estimated angler cancer risk based on the human health criterion (consumption of aquatic organisms only) adjusted to reflect the fish consumption rates used in this analysis.

3 Post-rule estimated angler cancer risk based on the aquatic life criterion, which is roughly 75 percent more stringent than the human health criterion, and the fish consumption rates used in this analysis.

Exhibit 3-19

POTENTIAL SAN FRANCISCO BAY CANCER HEALTH BENEFITS TO RECREATIONAL ANGLERS UNDER THE CALIFORNIA TOXICS RULE: ESTIMATED POST-RULE SAN FRANCISCO BAY ANGLER RISKS AND PERCENT REDUCTION RELATIVE TO BASELINE[1]

	Baseline		Post-rule					
			Achieve Post-rule Criteria Based on Risk Level of 1×10^{-6} for the General Population			Achieve Post-rule Criteria Based on Risk Level of 1×10^{-5} for the General Population		
Contaminant	**Individual Excess Lifetime Cancer Risk (21.4 - 49.6 g/day)**	**Population Cancer Risk (excess cases per year)**	**Individual Excess Lifetime Cancer Risk (21.4 - 49.6 g/day)**	**Population Cancer Risk (excess cases per year)**	**Percent Reduction**	**Individual Excess Lifetime Cancer Risk (21.4 - 49.6 g/day)**	**Population Cancer Risk (excess cases per year)**	**Percent Reduction**
Chlordane[2]	3.9×10^{-6} - 9.1×10^{-6}	0	3.3×10^{-6} - 7.6×10^{-6}	0	16 %	3.9×10^{-6} - 9.1×10^{-6}	0	0 %
DDT[2]	4.9×10^{-6} - 1.1×10^{-5}	0	3.3×10^{-6} - 7.6×10^{-6}	0	33 %	4.9×10^{-6} - 1.1×10^{-5}	0	0 %
Dieldrin[2]	7.8×10^{-6} - 1.8×10^{-5}	0	3.3×10^{-6} - 7.6×10^{-6}	0	58 %	7.8×10^{-6} - 1.8×10^{-5}	0	0 %
Dioxin[2]	7.6×10^{-5} - 1.8×10^{-4}	<1 - <1	3.3×10^{-6} - 7.6×10^{-6}	0	96 %	3.3×10^{-5} - 7.6×10^{-5}	0 - <1	58 %
PCBs[2]	9.0×10^{-5} - 2.1×10^{-4}	<1 - <1	3.3×10^{-6} - 7.6×10^{-6}	0	96 %	3.3×10^{-5} - 7.6×10^{-5}	0 - <1	64 %
Total	**1.8×10^{-4} - 4.2×10^{-4}**	**<1 - 1**	**1.7×10^{-5} - 3.8×10^{-5}**	**0**	**91 %**	**8.3×10^{-5} - 1.9×10^{-4}**	**0 - <1**	**55 %**

1 Cancer risks associated with the contaminants listed in this exhibit represent more than 99 percent of the total estimated cancer risk for San Francisco Bay anglers.

2 Post-rule estimated angler cancer risk based on the human health criterion (consumption of aquatic organisms only) adjusted to reflect the fish consumption rates used in this analysis.

3 Post-rule estimated angler cancer risk based on the aquatic life criterion, which is roughly 75 percent more stringent than the human health criterion, and the fish consumption rates used in this analysis.

criteria has the potential to reduce this to zero cases per year. Post-rule individual excess lifetime cancer risks range between 1.7×10^{-5} and 3.8×10^{-5} for typical Bay area anglers. Post-rule risks for individual contaminants are 16 to 96 percent below baseline estimates. The largest reductions (96 percent) are associated with PCBs and dioxin.

Under Scenario 2, criteria based on a risk level of 1×10^{-5}, the total reduction in cancer risks is 55 percent. The resulting number of annual excess cancer cases is between zero and one for typical consumption. Baseline risks for chlordane, DDT, and dieldrin are not significantly reduced and consequently have no post-rule benefits. Post-rule risks for dioxin and PCBs, however, are 58 and 64 percent lower than baseline, respectively.

Noncancer Risk Benefits to Recreational Anglers

Calculation of Post-Rule Fish Tissue Contaminant Concentrations

In estimating the potential health benefits from reduced noncancer risk, we focused on the contaminants that represent 97 percent of the risk for freshwater and San Francisco Bay anglers. Post-rule noncancer risks for these contaminants are based on the rule's human health standard for consumption of aquatic organisms. Under Scenario 1, we assume post-rule water quality meets these criteria, based on a risk level of 1×10^{-6} individual excess lifetime cancer risk for the general population. Under Scenario 2, we assume a risk level of 1×10^{-5} for the general population. To estimate post-rule noncancer risks for these contaminants, we back-calculated fish tissue contaminant levels from these target risk levels and applied the same methodology as was used to estimate baseline noncancer risks. For mercury, which is a noncarcinogen, we back-calculated the post-rule fish tissue concentrations from the noncancer risk target goal (HQ=1.0).

Freshwater Noncancer Benefits to Recreational Anglers

The results of the freshwater benefits analysis for noncancer effects are presented in Exhibit 3-20. Assuming criteria based on a risk level for the general population of 1×10^{-6}, noncancer risks for freshwater anglers decrease by 67 percent post-rule. The baseline hazard index ranges from 2.3 to 5.4 for freshwater anglers; once fully implemented, the rule has the potential to reduce this to 0.8 to 1.8. Hazard quotients for typical anglers for chlordane and DDT are less than one in both baseline and post-rule conditions, although the rule reduces the HQs for both contaminants by 70 and 87 percent, respectively. PCBs fall from the 1.4 to 3.3 baseline HQ to 0.1 to 0.2 after the rule, a reduction of 94 percent. Baseline risks for mercury are not significantly reduced under this rule, and therefore have no post-rule benefits.

Exhibit 3-20

POTENTIAL FRESHWATER NONCANCER HEALTH BENEFITS TO RECREATIONAL ANGLERS UNDER THE CALIFORNIA TOXICS RULE: ESTIMATED POST-RULE FRESHWATER ANGLER RISKS AND PERCENT REDUCTION RELATIVE TO BASELINE[1]

Contaminant	Baseline	Post-rule: Achieve Post-rule Criteria Based on Risk Level of 1×10^{-6} for the General Population		Post-rule: Achieve Post-rule Criteria Based on Risk Level of 1×10^{-5} for the General Population	
	Individual Risk Hazard Quotient (21.4 - 49.6 g/day)	Individual Risk Hazard Quotient (21.4 - 49.6 g/day)	Percent Reduction	Individual Risk Hazard Quotient (21.4 - 49.6 g/day)	Percent Reduction
Chlordane[2]	0.14 - 0.31	0.04 - 0.01	70 %	0.14 - 0.31	0 %
DDT[2]	0.15 - 0.34	0.02 - 0.04	87 %	0.15 - 0.34	0 %
Mercury[3]	0.62 - 1.44	0.62 - 1.44	0 %	0.62 - 1.44	0 %
PCBs[2]	1.40 - 3.30	0.08 - 0.19	94 %	0.82 - 1.91	41 %
Hazard Index	**2.31 - 5.39**	**0.76 - 1.77**	**67 %**	**1.73 - 4.00**	**25 %**

1 Noncancer risks associated with the contaminants listed in this exhibit represent 97 percent of the total estimated cancer risk for freshwater anglers.

2 Post-rule estimated angler noncancer risk based on the human health criterion (consumption of aquatic organisms only) cancer risk targets adjusted to reflect the fish consumption rates used in this analysis.

3 Post-rule estimated angler noncancer risk based on the human health criterion (consumption of aquatic organisms only) noncancer risk target of Hazard Quotient = 1.0.

Under Scenario 2, protection to 1 x 10^{-5}, the total reduction in noncancer risks is 25 percent, for a post-rule hazard index of 1.7 to 4.0 for typical anglers. Baseline risks for chlordane, DDT, and mercury already meet the 1 x 10^{-5} risk level, and consequently have no post-rule benefits. Post-rule risks for PCBs, however, are 41 percent lower than baseline, and have a post-rule HQ of 0.8 to 1.9 for typical anglers.

San Francisco Bay Noncancer Benefits to Recreational Anglers

The results of the San Francisco Bay benefits analysis for noncancer effects are presented in Exhibit 3-21. Assuming criteria based on a risk level of 1 x 10^{-6} for the general population, noncancer risks for Bay area anglers decrease by 76 percent due to the rule. The baseline hazard index ranges from 3.5 to 8.2 for Bay area anglers; once fully implemented, the rule has the potential to reduce this to 0.9 to 2.0. Hazard quotients for dioxin and PCBs each fall by 96 percent. Post-rule HQs for both compounds are less than one. Baseline risks for mercury already meet the rule's goal, and therefore have no post-rule benefits.

Under Scenario 2, criteria based on a risk level for the general population of 1 x 10^{-5}, the total reduction in noncancer risks in San Francisco Bay is 49 percent, resulting in a post-rule hazard index of 1.8 to 4.2 for typical anglers. Post-rule risks for dioxin and PCBs decrease by 57 and 64 percent, respectively. The post-rule HQ for dioxin is less than one, while the post-rule HQ for PCBs remains greater than 1.0 within the typical consumption range. Baseline risks for mercury already meet the rule's goal, and therefore have no post-rule benefits.

CONCLUSIONS: BASELINE RISKS AND POST-CTR BENEFITS TO RECREATIONAL ANGLERS

Our analysis shows that the potential baseline health risks associated with consumption of fish containing toxic pollutants for both freshwater and San Francisco Bay anglers are significant. Individual risk levels for freshwater anglers are slightly lower than those for San Francisco Bay anglers. Due to the larger population of freshwater anglers, however, the population risks for this group are roughly 15 times larger than those for Bay anglers. An analysis of post-CTR benefits suggests that there may be substantial reductions in recreational angler health risks. These baseline risks and CTR-associated benefits are summarized below.

Exhibit 3-21

POTENTIAL SAN FRANCISCO BAY NONCANCER HEALTH BENEFITS TO RECREATIONAL ANGLERS UNDER THE CALIFORNIA TOXICS RULE: ESTIMATED POST-RULE SAN FRANCISCO BAY ANGLER RISKS AND PERCENT REDUCTION RELATIVE TO BASELINE[1]

		Post-rule			
	Baseline	Achieve Post-rule Criteria Based on Risk Level of 1×10^{-6} for the General Population		Achieve Post-rule Criteria Based on Risk Level of 1×10^{-5} for the General Population	
Contaminant	Individual Risk Hazard Quotient (21.4 - 49.6 g/day)	Individual Risk Hazard Quotient (21.4 - 49.6 g/day)	Percent Reduction	Individual Risk Hazard Quotient (21.4 - 49.6 g/day)	Percent Reduction
Dioxin[2]	0.51 - 1.17	0.02 - 0.05	96 %	0.22 - 0.51	57 %
Mercury[3]	0.75 - 1.74	0.75 - 1.74	0 %	0.75 - 1.74	0 %
PCBs[2]	2.26 - 5.24	0.08 - 0.19	96 %	0.82 - 1.91	64 %
Hazard Index	**3.52 - 8.18**	**0.85 - 1.98**	**76 %**	**1.79 - 4.16**	**49 %**

1 Noncancer risks associated with the contaminants listed in this exhibit represent 97 percent of the total estimated cancer risk for San Francisco Bay anglers.

2 Post-rule estimated angler noncancer risk based on the human health criterion (consumption of aquatic organisms only) cancer risk targets adjusted to reflect the fish consumption rates used in this analysis.

3 Post-rule estimated angler noncancer risk based on the human health criterion (consumption of aquatic organisms only) noncancer risk target of Hazard Quotient = 1.0.

Summary of Potential Baseline Cancer
Risks to Recreational Anglers

- Individual excess lifetime cancer risks from fish consumption for freshwater anglers range from 1.5×10^{-4} to 3.5×10^{-4} for typical angler consumption (i.e., 21.4 to 49.6 g/day).

- Upper-bound consumption (i.e., 90th percentile fish consumption of 107.1 g/day) for freshwater anglers results in an individual excess lifetime cancer risk of 7.6×10^{-4}.

- California's freshwater angling population will incur between 5 and 11 cases of cancer each year (based on typical consumption rates and a population of approximately 2.2 million freshwater anglers).

- Individual excess lifetime cancer risks for typical San Francisco Bay anglers range from 1.8×10^{-4} to 4.3×10^{-4}.

- Upper-bound consumption for San Francisco Bay anglers results in an individual excess lifetime cancer risk of 9.2×10^{-4}.

- San Francisco Bay's angling population may incur less than one to one case of cancer each year, or a total of 23 to 53 cases over 70 years (based on typical consumption and a Bay area angler population of approximately 125,000 individuals).

- The San Francisco Bay case study provides quantitative health risk estimates for 125,000 recreational anglers fishing in the Bay area. The CTR, however, also governs water quality in California's other inland bays and estuaries. The case study does not include risk estimates for the 500,000 to 600,000 bay and estuary anglers that fish outside of San Francisco Bay.

These baseline cancer risks are dominated by a small number of contaminants. PCBs and toxaphene account for nearly 58 percent of the baseline freshwater angler cancer risk. DDT, dieldrin, and chlordane account for an additional 40 percent of the risk. In San Francisco Bay, PCBs and dioxin dominate angler cancer risks. PCBs account for nearly 50 percent of the baseline cancer risk while dioxin contributes an additional 40 percent.

Summary of Potential Baseline Noncancer
Risks to Recreational Anglers

- The hazard index for freshwater anglers with typical fish consumption (i.e., 21.4 to 49.6 grams per day) ranges from 2.4 to 5.5.
- The hazard index for freshwater anglers with 90th percentile fish consumption (i.e., 107.1 grams per day) is 11.9.
- The hazard index for San Francisco Bay anglers with typical fish consumption ranges from 3.6 to 8.4.
- The hazard index for San Francisco Bay anglers with 90th percentile fish consumption is 18.1.

Like cancer risks, baseline noncancer risks are dominated by a relatively small number of contaminants. Again, PCBs with an HQ of 1.4 to 3.3 at typical consumption, account for the majority of baseline noncancer risks for freshwater anglers (60 percent). Mercury contributes an additional 26 percent of the baseline noncancer risk with an HQ of 0.6 to 1.4 under typical consumption. These are the only freshwater contaminants with hazard quotients greater than 1.0 within the typical or 90th percentile fish consumption scenarios.

PCBs also account for the majority of baseline noncancer risk for San Francisco Bay anglers -- 62 percent. Mercury and dioxin are the only other contaminants with a hazard quotient as high as 1.0 for typical or 90th percentile Bay area anglers. Mercury's baseline hazard quotient ranges from 0.8 to 1.7 at the typical consumption rate, increasing to 3.8 at 90th percentile consumption. Dioxin has a baseline HQ ranging from 0.5 to 1.2 for typical consumption, and increases to 2.5 at 90th percentile consumption.

The freshwater and San Francisco Bay baseline angler risk estimates are subject to uncertainties associated with the series of assumptions included in the methodology for this analysis. For example:

- Relying on contaminant concentrations measured in raw fish tissue to estimate exposure overstates risks;
- Not considering fish consumption by anglers' families understates baseline population risks for anglers and individual risks for sensitive subgroups; and
- Assuming that contaminants not detected above the MDL are present at one-half of the MDL may either under- or overstate risks.
- Not estimating health risks associated with consuming contaminated commercial fish underestimates baseline risks.

Overall, we found that these and other uncertainties do not alter our finding that both freshwater and Bay anglers face potentially significant health risks from consumption of fish contaminated with toxics.

In addition, we have explored the environmental justice implications of angler health risks. We have examined whether differences in fish consumption patterns, including fish consumption rates and preparation methods, create the potential for certain ethnic or income subgroups of the angler population to face disproportionate health risks. According to the primary study we used to derive fish consumption rates, ethnic and income groups in California do not differ substantially in their fish consumption rates. Furthermore, the typical and 90th percentile consumption rates used in our analysis are applicable to virtually the entire angler population.

Data on food preparation methods from this same study suggest that some individuals may face additional risks due to the consumption of whole fish, including the intestines. Moreover, risks for roughly 50 percent of these individuals may be underestimated because they prepare and eat fish with the skin, while the freshwater tissue samples were analyzed without skin. This is not the case for Bay angler risk estimates, since Bay fish tissue samples were prepared according to the most frequent means of consumption for each species.

Potential Benefits of the CTR

An analysis of the potential health benefits associated with achieving the water quality criteria established by the California Toxics Rule suggests that once the rule is fully implemented, substantial reductions in angler health risks may occur.

- We estimated that post-rule cancer risks, under criteria based on a risk level of 1×10^{-6} for the general population, for freshwater and San Francisco Bay anglers could be as much as 91 percent lower than baseline levels.

- The estimated population risk for freshwater anglers decreases from between 5 and 11 cases per year to one or fewer cases per year.

- Assuming post-rule water quality meets the rule's proposed criteria based on a risk level of 1×10^{-6} for the general population, the individual excess lifetime cancer risks for anglers consuming fish at typical rates would range from 1.4×10^{-5} to 3.3×10^{-5}.

- For San Francisco Bay anglers, population cancer risk is estimated to decrease from the baseline of one or fewer cases per year (23 to 53 cases over 70 years) to zero cases per year as a result of the rule.

- Assuming the rule is implemented and achieves ambient water quality criteria based on a risk level of 1×10^{-6} for the general population, post-rule individual excess lifetime cancer risks for these typical Bay area anglers could range from 1.7×10^{-5} to 3.8×10^{-5}.

- Noncancer risks for California anglers may decrease by as much as 67 percent for typical freshwater anglers and 76 percent for typical San Francisco Bay anglers. The HI for freshwater anglers is estimated to decrease from the current range of 2.4 to 5.5 to the potential post-rule level of 0.8 to 1.8. These results suggest that if the rule achieves ambient water quality criteria, it could effectively eliminate noncancer risks associated with PCBs, chlordane, and DDT.

- For San Francisco Bay anglers, the HI is estimated to decrease from the 3.6 to 8.4 baseline range to the post-rule range of 0.9 to 2.0 at the typical consumption level. The results suggest that if the rule achieves ambient water quality goals, typical San Francisco Bay anglers are unlikely to face a risk of adverse noncancer health effects from dioxin or PCBs.

REFERENCES

California EPA, State Water Resources Control Board, *Toxic Substances Monitoring Program,* Data Reports, June 1991 (91-1WQ), May 1992 (92-1WQ), January 1993 (90-1WQ), and June 1993 (93-1WQ).

California Department of Fish and Game Inland Fisheries Division, *Sacramento River System Sport Fish Catch Inventory, Final Performance Report*, June 30, 1995.

California OEHHA, *A Study of Chemical Contamination of Marine Fish from Southern California Volume II: Comprehensive Study,* 1991.

Lance, L., Papanek, P., Ward, C., and Peterson, J, *Breast Milk Contaminants and Fresh Fish Consumption in Southern California: Results of a Pilot Survey.* DRAFT. Prepared by the Department of Health Services, County of Los Angeles, 1988.

National Academy of Sciences, *Seafood Safety*. Committee on Evaluation of the Safety of Fishing Products, National Academy Press, Washington D.C., 1991.

National Marine Fisheries Service, *National Marine Recreational Fishery Statistics Survey, Pacific Coast*, 1987-1989 and 1993.

National Marine Fisheries Service, *Results of the Bay Area Sportfish Economic Study*, NOAA-TM-NMFS-SWFC-78, August 1987.

San Francisco Regional Water Quality Control Board, *Contaminant Levels in Fish Tissue from San Francisco Bay, Final Draft Report*, December 1994.

Santa Monica Bay Restoration Project, *Santa Monica Bay Seafood Consumption Study*, prepared by Southern California Coastal Water Research Project and MBC Applied Environmental Sciences, June 1994.

Save San Francisco Bay Association's, *Eating Seafood from San Francisco Bay: a Report on Fishing and Consumption Patterns, and a Review of Government Monitoring and Assessment of Health Risk from Contaminants in the Bay, Draft,* April 1995.

REFERENCES
(continued)

USEPA, National Center for Environmental Assessment, Office of Research and Development. *PCBs: Cancer Dose-Response Assessment and Application to Environmental Mixtures*, EPA/600/P-96/001F, September 1996.

USEPA, *Regulatory Impact Analysis of the Final Great Lakes Water Quality Guidance, Final Report,* Office of Science and Technology, March 1995.

USEPA, *Mercury Study Report to Congress, Volume VI: Characterization of Human Health and Wildlife Risks from Anthropogenic Mercury Emissions in the United States, Draft,* Office of Air Quality Planning and Standards and Office of Research and Development, December 12, 1994.

USEPA, *Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories: Volume 1, Fish Sampling and Analysis*, Office of Water, EPA 823-R-93-002, August 1993.

USEPA, *National Study of Chemical Residues in Fish, Volumes I and II.* Office of Science and Technology, EPA 823-R-92-008a,b, September 1992.

US Fish and Wildlife Service, 1991 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation, California, July 1993.

Voiland, MP, DL Gall, DJ Lisk, and DB MacNeill, "Effectiveness of Recommended Fat-Trimming Procedures on the Reduction of PCB and Mirex Levels in Brown Trout from Lake Ontario," *Journal of Great Lakes Research*, volume 17, number 4, pages 454-460, 1991.

Zabik, M.E and M.J. Zabik."Tetrachlorodibenzo-p-dioxin Residue Reduction by Cooking/Processing of Fish Fillets Harvested from the Great Lakes," Bulletin of Environmental Contamination and Toxicology. V.55, 1995, pp. 264-269.

ECONOMIC BENEFITS CHAPTER 4

INTRODUCTION

This chapter describes and estimates a variety of potential economic benefits associated with meeting water criteria established by the California Toxics Rule (CTR). Exhibit 4-1 summarizes these potential benefits. Because of data, time, and budgetary constraints, we have valued only use benefits associated with recreational fishing and related non-use benefits. In addition, we have monetized some of the health benefits presented in Chapter 3. Key results of our evaluation include:

- Monetized benefits associated with achieving toxic water quality criteria established by the CTR are estimated for recreational fishing, human health cancer effects, and passive use values only. These benefits are significant, ranging from a low of $62 million per year to an upper bound of approximately $600 million per year.

- Recreational fishing benefits are valued at between $35 and $196 million per year. Related non-use benefits are estimated to be $17 to $294 million. Finally, avoided cancer deaths are valued at between $10 and $110 million per year.

- A number of other economic benefits are expected to accrue when water quality criteria are met. However, we have not quantified or monetized these comprehensively. They include: increased value for commercial fishing; drinking water treatment, sludge treatment, and dredged material management cost savings; increased property values; increased value and participation in recreational hunting and other near-stream activities; avoided cost of illness associated with consumption of commercially caught seafood; and avoided costs of endangered species management.

Exhibit 4-1

SUMMARY OF POTENTIAL ANNUAL ECONOMIC BENEFITS ASSOCIATED WITH ACHIEVING WATER QUALITY STANDARDS ESTABLISHED BY THE CALIFORNIA TOXICS RULE

Benefit Category	Lower Bound Estimate (Millions $1996)(1)(2)	Upper Bound Estimate (Millions $1996[1])
USE VALUES		
Improved Recreational Fishing	$35	$196
Improved Recreational Hunting	$ -- Not Estimated	$ -- Not Estimated
Water Enhanced Recreation	$ -- Not Estimated	$ -- Not Estimated
Improved Commercial Fisheries	$ -- Not Estimated	$ -- Not Estimated
Drinking Water Treatment Savings	$ -- Not Estimated	$ -- Not Estimated
Sludge Treatment Savings	$ -- Not Estimated	$ -- Not Estimated
Property Values	$ -- Not Estimated	$ -- Not Estimated
Avoided cost of endangered species management and associated land use restrictions	$ -- Not Estimated	$ -- Not Estimated
Human Health (3)		
Reduced cancer risk -- anglers	$10	$110
Reduced non-cancer risk --anglers	67% reduction in Hazard Index; $ -- Not Estimated	76% reduction in Hazard Index; $ -- Not Estimated
Reduced health risk to some subsistence anglers	$ -- Not Estimated	$ -- Not Estimated
NON-USE		
Bequest and Existence Values	$17	$294
Ecological		
Reduced morbidity/mortality to aquatic and terrestrial wildlife; improved integrity of aquatic and aquatic-dependent ecosystems	- 815,000 acres of bays, harbors, estuaries, lakes, and wetlands - 4,000 miles of rivers	- 815,000 acres of bays, harbors, estuaries, lakes, and wetlands - 4,000 miles of rivers
Improved conditions in habitat supporting fish spawning/migration	- 175,000 acres of bays/harbors - 52,000 acres of estuaries - 102,000 acres of lakes - 11,000 acres of saline lakes - 1,000 miles of rivers	- 175,000 acres of bays/harbors - 52,000 acres of estuaries - 102,000 acres of lakes - 11,000 acres of saline lakes - 1,000 miles of rivers
Improved conditions in habitat supporting threatened and endangered species	- 180,000 acres of bays, harbors and estuaries - 230,000 acres saline lakes - 1,900 river miles	- 180,000 acres of bays, harbors and estuaries - 230,000 acres saline lakes - 1,900 river miles
TOTAL	**$62 + $ Benefits not Estimated**	**$600 + $ Benefits not Estimated**

(1) Dollars converted to first quarter 1996 using Gross Domestic Product implicit price deflator.
(2) $ -- Not Estimated = Dollar benefits expected to accrue, but not yet monetized.
(3) Health risks estimated for 80 percent of California anglers.

- Thus, total benefits associated with achieving the water quality criteria established by the CTR are expected to exceed the total of the monetized benefits ($62 million to $600 million per year).

It is important to note that these benefits will not accrue until California fully attains the water quality standards through various programs to reduce point and non-point source toxic discharges.

The remainder of this chapter describes these benefits in more detail. The chapter is organized as follows:

- First, we briefly summarize the methodology that we have used in estimating the quantitative benefits associated with the rule.

- Second, we evaluate the recreational use value benefits that may be realized when toxic water quality criteria are achieved. Specifically, we examine benefits associated with an improved recreational fishing experience and increased recreational fishing participation.

- Third we estimate the non-use benefits associated with meeting toxic water quality criteria.

- Next we monetize the health benefits to anglers described in Chapter 3.

- Finally, we briefly discuss a number of benefits that may be significant, but which cannot be readily quantified or monetized for this benefits assessment.

METHODOLOGY

From an economic perspective, reducing toxic discharges to achieve water quality standards established by the CTR will contribute to increased protection and restoration of currently impaired bays, estuaries, lakes, streams, rivers, and wetlands that produce a stream of services to the 31 million inhabitants of California. These aquatic systems support commercial fishing and recreational uses such as fishing, wildlife viewing, hiking, hunting, and swimming. Further they serve as sources of drinking water and provide process and cooling water to industry. In addition, if the resources are not currently used, they may be used in the future; preserving the right to exercise future options to visit and use the resource has intrinsic value. Finally, California's aquatic systems provide benefits to society entirely separate from their use. These "non-use" services include an existence value derived from simply knowing the resource exists in a preserved state; and a bequest

value derived from knowing that the resource will continue to exist for the benefit of future generations. Exhibit 4-2 presents a summary of these and other potential benefit categories that typically are associated with improvements in aquatic systems.

Exhibit 4-2

POTENTIAL BENEFITS OF WATER QUALITY IMPROVEMENTS

Use Benefits	
In-Stream	• Commercial fisheries, shellfisheries, and aquaculture; navigation • Recreation (fishing, boating, swimming, etc.) • Subsistence fishing • Human health risk reductions
Near Stream	• Water-enhanced non-contact recreation (picnicking, photography, jogging, camping, etc.) • Nonconsumptive use (e.g., wildlife observation)
Option Value	• Premium for uncertain future demand • Premium for uncertain future supply
Diversionary	• Industry/commercial (process and cooling waters) • Agriculture/irrigation • Municipal drinking water (treatment cost savings and/or human health risk reductions)
Aesthetic	• Residing, working, traveling and/or owning property near water, etc.
Non-Use Benefits	
Bequest	• Intergenerational equity
Existence	• Stewardship/preservation • Vicarious consumption
Ecological	• Reduced mortality/morbidity for aquatic and terrestrial wildlife • Improved reproductive success for aquatic and terrestrial wildlife • Increased diversity of aquatic and terrestrial wildlife • Improved conditions for successful recovery of threatened and endangered species • Improved integrity of aquatic and aquatic-dependent ecosystems

Source: U.S. EPA

Economists quantify and value improvements in water quality by estimating overall changes in consumer and producer surplus associated with that resource. Consumer surplus is the individual's willingness to pay for the services the resource provides (now and into the future), net of any costs associated with enjoying those services. For example, if a birder pays $10 in gas, entrance fees, equipment, etc. to drive to a wildlife area to view birds, and she would be willing to pay up to $40 to visit the site, then the birder is receiving $30 in consumer surplus as a result of the trip.[1]

Estimating the consumer surplus that is associated with water quality improvements involves several steps, as summarized in Figure 4-1. As shown, the first step requires evaluating how reducing discharges will lead to changes in physical, chemical and/or biological indicators of aquatic system water quality and water-dependant resources. A key challenge in this step is to adequately measure or predict the relationship between changes in the aquatic system parameter (e.g., reduced contamination by toxic pollutants) and the appropriate biological or physical receptor of the induced change.

The second step requires evaluating the range of uses and activities that will be affected by improvements in water quality, the scope and magnitude of which will vary by site and by water quality parameter (see Exhibit 4-2). Evaluating how these uses will change requires developing accurate estimates of baseline environmental conditions and anticipating future levels of activity that may occur as a result of specific post-rule water quality improvements. The final step requires quantifying and, to the extent possible, monetizing the changes in human use and activity estimated in the previous step.

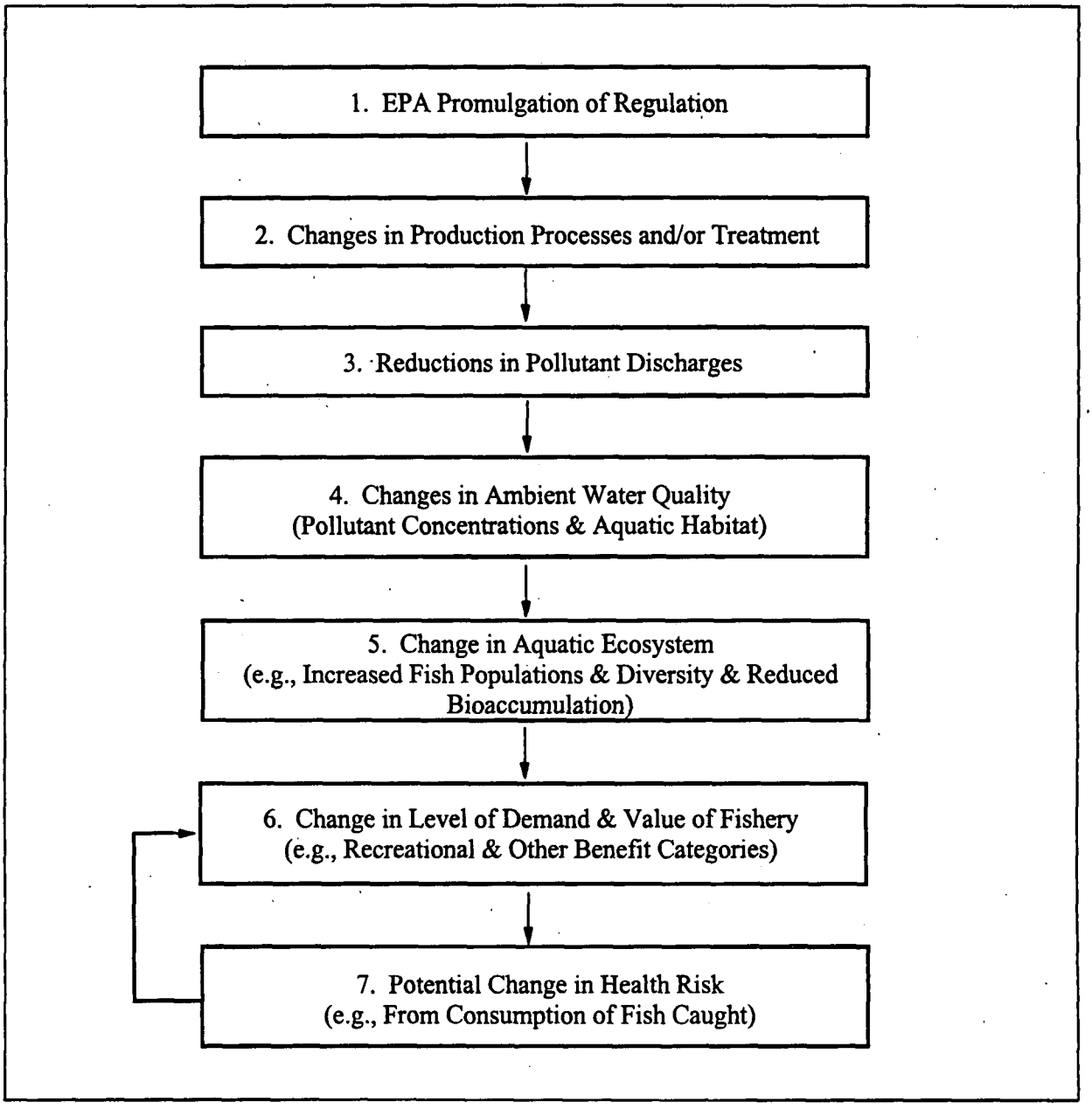
Evaluating the specific economic benefits attributable to meeting water quality criteria is theoretically straightforward but in reality is often difficult to do at both the site-specific and regional level because of limited or non-existent scientific, economic, and/or social data. In this assessment, where accurate or complete data are not available for each of the water resources evaluated, we have applied a set of reasonable assumptions to obtain lower and upper bound estimates that represent a realistic range of potential benefits likely to occur, rather than developing a single point estimate of benefits.

---

[1] In a similar fashion, producer surplus represents the difference between the cost of producing a good/service and the price of that good/service.

Figure 4-1

STEPS IN WATER QUALITY BENEFITS ANALYSIS



In this analysis we estimated baseline water resource conditions for the entire State using data from California's Water Quality Assessment (WQA) database.[2] Benefits were then calculated assuming that water quality programs will be implemented to reduce point and non-point discharges, thereby achieving the water quality criteria specified in the CTR.

In evaluating the value of the improvement in water quality, we measure the net willingness to pay for these services under baseline conditions relative to conditions when toxic criteria are achieved statewide. Because many natural resource services are not traded in the marketplace, willingness to pay information cannot be directly obtained from observed behavior. Consequently, we can apply a variety of techniques to value natural resource services, or to estimate the economic benefits of improvements in environmental quality. These methods attempt to determine individuals' willingness to pay for natural resource services directly, through survey research, or indirectly, through the examination of behavior in related markets. They include such techniques as contingent valuation; analysis of added or avoided costs caused by changes in environmental quality; and revealed preference methods, such as travel cost analysis and hedonic property value studies.[3]

While each of these methods is potentially applicable to the California benefits assessment, budget limitations did not support implementation of these analyses. In lieu of such analysis, we have estimated baseline and post-rule economic benefits using a benefits transfer approach: the application of benefits estimates, contingent valuation studies, functions, data, and/or models developed in other areas to estimate benefits in a similar but alternative context. When possible we have adjusted the functions, data and/or models used to reflect California-specific characteristics. When applying dollar values from studies performed prior to 1996, we adjust to $1996 (first quarter) using the GDP deflator.[4] Finally, we present benefit estimates in terms of *annual*, rather than annualized values because of the difficulty in predicting a stream of benefits expected to occur in the future, and uncertainty about the timing associated with achieving the water quality criteria.

---

[2] The WQA is a compilation of data from California's nine regional Water Quality Control Boards and is organized by region and by waterbody type. It contains a range of information on surface water pollution, including the pollutants that adversely affect water quality in bodies of water that have been evaluated, the sources of pollution, the beneficial uses impaired, and an overall rating of water quality. See Chapter 2 for a more detailed description.

[3] For a comprehensive summary of approaches available to measure market and non-market benefits, see U.S. EPA, *Ecological Benefits Assessment Framework*, draft, prepared for EPA Social Sciences Discussion Group, EPA Science and Policy Council, 1996.

[4] Gross Domestic Product Implicit Price Deflator, U.S. Department of Commerce, Bureau of Economic Analysis.

It is important to point out the limitations of this standard economic approach to estimating the full range of environmental benefits expected to accrue when water quality standards and criteria are met.[5] First, the true value of natural resources probably is often underestimated by humans. Since natural goods and services are provided free of charge, their ecological value (and potential value) is probably not fully appreciated. Further, because ecosystem functional services are complex, incompletely understood, and difficult to quantify, the values of these services have generally been ignored in valuation exercises.[6] Third, people value money differently, so that aggregate prices fail to account for the different values people place on the evaluation unit itself. Fourth, different social groups, interest groups, and individuals value resources differently, but "damages" represent aggregate losses without accounting for distributional changes in resource use. For these reasons, we believe that the benefits associated with achieving the water quality criteria established by the CTR cannot be fully monetized, and when benefits are monetized, they often are underestimated. Other specific methods, assumptions, and limitations are described in greater detail in the sections that follow.

The benefit assessment methods used in this chapter are similar to the approach used by EPA in the Regulatory Impact Assessment of Proposed Effluent Limitation Guidelines and Standards for the Metal Products and Machinery Industry (Phase I) and the Regulatory Impact Analysis for the Agency's Great Lakes Water Quality Guidance, which establishes numeric criteria for toxic pollutants similar to those proposed for California.[7]

RECREATIONAL FISHING BENEFITS ASSOCIATED WITH MEETING WATER QUALITY CRITERIA

As described in Chapters 5 and 6 of this report, reducing toxic contamination to meet water quality criteria established under the CTR may increase the diversity, stability, and overall health of aquatic ecosystems throughout California, leading to overall improvement in recreational and

---

[5] For a more detailed discussion of the limited ability of traditional economic analyses to capture ecological benefits, see U.S. EPA; *A Brief Overview of Natural Resource Valuation Issues and Methodologies*, 1994.

[6] For a more detailed discussion, see and Costanza, Robert, et al., "The Value of the World's Ecosystem Services and Natural Capital," *Nature*, May 15, 1997.

[7] See *RIA of Proposed Effluent Limitation Guidelines and Standards for the Metal Products and Machinery Industry (Phase I)*, U.S. EPA, 1995; and *Regulatory Impact Analysis of the Proposed Great Lakes Water Quality Guidance, Final Report*, U.S. EPA, 1995.

commercial fisheries.[8] In addition, decreasing toxics to California waters also may result in reduced toxics contamination of recreational and commercial fish tissue, thereby reducing public concern about the adverse health effects of consuming contaminated fish.

To evaluate the economic effect of these improvements, we examine two components of recreational fishing benefits: (1) the value of improving the recreational experience of current participants; and (2) the value of increased participation in the activity. The basic microeconomic theory behind these components is reflected in Figure 4-2. Demand for a given recreational activity increases because reduced toxic contamination of aquatic systems makes the activity more attractive. This change in consumer preferences is shown by movement of the demand curve from D_1 to D_2. The area ABCD shows the change in consumer surplus for participants already engaged in the recreational activity. Area ADE shows the increase in consumer surplus that results when new participants engage in the recreational activity, or when current participants increase activity beyond the current level.

This section discusses our approach for valuing these two components for recreational fishing in California. Generally, we employ a benefits transfer methodology that incorporates estimates from previous studies to value changes in recreational activity in California. Although this analysis is applied at the statewide level, and therefore does not address the numerous site-specific considerations that will affect fishing behavior at each discrete local area, the results are intended to provide a rough approximation of the potential range of Statewide benefits associated with meeting water quality criteria established under the CTR.

Value of Improved Fishing Experience

As described in this report, waters throughout California are affected by toxic pollutants such as metals, selenium, pesticides, mercury, and priority organics. Reductions in toxics loadings are expected to contribute to improved conditions for fish spawning and/or migration in more than 223,000 acres of bays/harbors and estuaries, 102,000 acres of lakes, 1,000 miles of rivers and streams, and 11,000 acres of saline lakes.[9] Further, toxic contamination is responsible for 12 fish consumption advisories currently in place throughout the State in waters covered by the CTR, including advisories for selenium, mercury, dioxin, DDT, chlordane, and PCBs (see Chapter 3). In addition, California EPA has issued consumption warnings for 10 ocean sites in California that are not included in the CTR as enclosed bays or estuaries.[10]

---

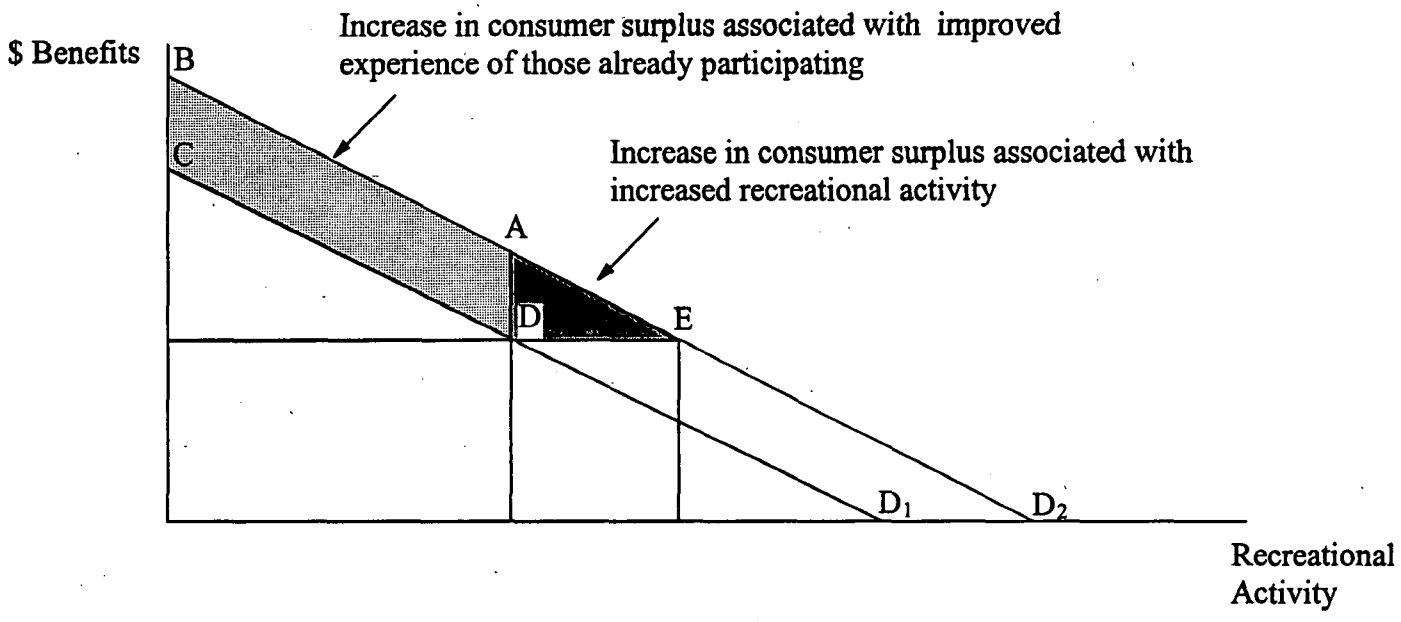
[8] See Setzler-Hamilton, Eileen, et al., "Striped Bass Populations in Chesapeake and San Francisco Bays: Two Environmentally Impacted Estuaries," *Marine Pollution Bulletin*, Vol. 19, No. 9, pp. 466-477.

[9] See chapter 5 for a more detailed description of these benefits.

[10] Fish consumption warnings for sites not covered by the CTR include Newport Pier, Redondo Pier, Malibu Pier, Short Bank, Malibu/Pint Dume, Point Vicente, Palow Verdes-Northwest, White's Point, Los Angeles Harbor/Long Beach Breakwater (ocean side) and Horseshoe Kelp.

Figure 4-2

COMPONENTS OF VALUE IN RECREATIONAL BENEFITS ESTIMATES



Knowledge of the degree of toxic contamination in waterbodies throughout the State, plus awareness of fish consumption advisories in specific sites, may affect how anglers appreciate their fishing experience. Consequently, reducing toxics in California waters to meet water quality criteria established by the CTR may result in an overall increase in the value that anglers place on fishing.

EPA found little available research on the incremental value to California anglers of reducing toxic contamination of surface waters applicable to the CTR.[11] However, the potential significance of how anglers value a fishery relatively free of toxics is illustrated by a 1992 study of the Wisconsin Great Lakes open water sport fishery.[12] In this study, Lyke estimated the current value of sport fishing on the Wisconsin Great Lakes, and the potential benefits of a "contaminant free" fishery. In a survey, Lyke posed questions that elicited willingness to pay for a fishery "completely free of pollutants that may threaten human health."[13] The findings indicate that these values range between 11.1 and 31.3 percent of the value of the fishery under current conditions.

EPA transferred the Lyke results by first estimating the number of fishing days in California that occur in toxic-impaired waters, distinguishing between waterbody type (e.g., river, lake, estuary, etc.). Then, we multiplied the number of fishing days by an average consumer surplus for the different modes of fishing to obtain a baseline value of the fishery under current conditions. EPA then multiplied these numbers by 11 percent to 31 percent (from Lyke) to obtain the value of a "contaminant-free" fishery. These steps are described below and are summarized in Exhibit 4-3 below.[14]

---

[11] One study, which estimates California residents' willingness-to-pay to protect aquatic and aquatic-dependant wildlife from adverse effects of selenium in the Central Valley, could not be applied to this analysis because of data limitations (see Loomis et al, in Dinar, 1991).

[12] Lyke, A.J. "Discrete Choice Models to Value Changes in Environmental Quality: A Great Lakes Case Study", dissertation submitted to the Graduate School of the University of Wisconsin-Madison, 1993.

[13] Lyke, 1993. Note that the wording "contaminant free" was used in the Lyke survey instrument. We assume that respondents interpret "contaminant free" as meaning a fishery free of pollutants in concentrations that would threaten human health, not complete elimination of toxic pollutants. Note also that the area of Lake Michigan addressed in the Lyke study has been the focus of several fishing advisories. As we discuss below, there are uncertainties associated with using the results of this study to estimate benefits for California waters that may be less impaired.

[14] Several other EPA water quality benefits studies have taken this approach. See *Regulatory Impact Analysis of the Proposed Great Lakes Water Quality Guidance, Final Report*, U.S. EPA Office of Water, 1995; and *Regulatory Impact Assessment of Proposed Effluent Limitation Guidelines and Standards for the Metal Products and Machinery Industry (Phase I)*, U.S. EPA, 1995.

Estimating Toxic-Impaired Fishing Days

To apply Lyke's willingness to pay values, we must first estimate the amount of fishing activity that occurs on California waters affected by toxics. Estimates of total fishing days are taken from the Fish and Wildlife Service's 1991 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation, and are divided by waterbody type.[15] The survey does not report saltwater fishing days by waterbody type. Therefore, we have developed an estimate of saltwater days that assumes that half are associated with bays, 30 percent with estuaries, and 10 percent with saline lakes, with the remaining 10 percent representing open sea fishing on waters not addressed by the toxics criteria.[16] We further subdivide the estimate of fishing days in bays into San Francisco Bay and other California bays. We estimate the number of San Francisco Bay fishing days by multiplying the estimated number of San Francisco Bay anglers (125,000 anglers, taken from the fish consumption risk estimates previously described in Chapter 3) by the average number of days per angler (6.2).[17] The estimate of fishing days for other bays (1,974,350) is therefore the total number of bay days net of the estimated number of days in San Francisco Bay (775,000). Note that many of the fishing advisories in California have been issued since 1991, the year of the fishing activity data. Because advisories may discourage fishing activity, it is possible that current fishing activity is less than estimated. However, this factor may be offset by the growth in the California population, which would tend to increase the number of fishing days.

We then estimate the total number of toxics-affected fishing days. We scale the total number of fishing days for each waterbody type by the statewide estimate of surface water impaired by toxic pollutants.[18] This estimate is based on our analysis of California's Water Quality Assessment data, as discussed in detail in Chapter 2 of this report. For example, the WQA data indicate that for all

---

[15] U.S. Fish and Wildlife Service, *National Survey of Fishing, Hunting, and Wildlife-Associated Recreation -- California*, July 1993.

[16] The distribution of saltwater fishing days to different waterbody types is based on best professional judgment. If open sea fishing and coastal fishing not associated with enclosed bays and estuaries represents greater than 10 percent of all fishing activity, we may overstate benefits.

[17] Average days per angler taken from the Bay Area Sport Fish Economic Survey, as reported in Huppert, Daniel D., "Measuring the Value of Fish to Anglers: Application to Central California Anadramous Species," *Marine Resource Economics*, Vol. 6, pp. 89-107, 1989.

[18] As mentioned above, we define "impaired" waters as those that have been assessed and are rated by the State of California as medium or poor water quality for at least one toxic water quality pollutant or group of pollutants.

Exhibit 4-3

RECREATIONAL FISHING: POTENTIAL ANNUAL BENEFITS OF IMPROVED EXPERIENCE ($1996)

FRESHWATER FISHING	Statewide Fishing Days Per Year	Percent of Assessed Waters Toxics-Impaired**	Statewide Toxics-Affected Fishing Days	Day Value		Total Value		Lower Bound Increase in Willingness-to-Pay	Upper Bound Increase in Willingness-to-Pay
				Lower Bound	Upper Bound	Lower Bound	Upper Bound		
Lakes and Reservoirs	9,678,800	19%	1,838,972	$25	$35	$45,974,300	$64,364,020	$5,057,173	$19,952,846
Ponds	1,534,100	19%	291,479	$25	$35	$7,286,975	$10,201,765	$801,567	$3,162,547
Rivers and Streams	6,002,900	19%	1,140,551	$25	$35	$28,513,775	$39,919,285	$3,136,515	$12,374,978
SUBTOTAL:	17,215,800					$81,775,050	$114,485,07	$8,995,256	$35,490,372
SALTWATER FISHING									
Bays									
-- San Francisco Bay	775,000 *	69%	534,750	$50	$100	$26,737,500	$53,475,000	$2,941,125	$16,577,250
-- Other California Bays	1,974,350 *	51%	1,006,919	$50	$100	$50,345,925	$100,691,85	$5,538,052	$31,214,474
Estuaries	1,649,610 *	47%	775,317	$50	$100	$38,765,835	$77,531,670	$4,264,242	$24,034,818
Saline Lakes	549,870 *	69%	379,410	$50	$100	$18,970,515	$37,941,030	$2,086,757	$11,761,719
SUBTOTAL:	4,948,830					$134,819,77	$269,639,55	$14,830,175	$83,588,261
TOTAL	22,164,630					$216,594,82	$384,124,62	$23,825,431	$119,078,632

* Based on a total of 5,498,700 total saltwater fishing days. Assumes 50 percent in bays (e.g., pier fishing) 30 percent on estuaries, and 10 percent on saline lakes. Remainder is open sea fishing not addressed by the rule. Estimated fishing days for San Francisco Bay based upon estimated number of anglers from health risk analysis (125,000) multiplied by the average days per angler (6.2) from Huppert, 1989.

** EPA defines "impaired" waters as those assessed and rated by the State of California as medium or poor quality for at least one toxic pollutant or group of pollutants.

Sources: U.S. Fish & Wildlife Service, 1991 Survey of Fishing, Hunting, and Wildlife-Associated Recreation.
EPA analysis of 1994 California Water Quality Assessment data base (see Chapter 2).
Lyke, 1993
Studies in Exhibit 4-4

lakes and reservoirs, toxics affect 19 percent of all waters assessed. Therefore, we multiply the total lakes and reservoirs fishing days of 9,678,800 by 0.19 to obtain a statewide number of toxics-affected fishing days of 1.84 million.

Baseline Fishery Value

To estimate the value of toxics-affected fishing days, we multiply days by the applicable estimate of consumer surplus per fishing day. To best reflect the value of different types of fishing in California, we searched the literature for relevant studies. Exhibit 4-4 summarizes the result of this search. As shown, several freshwater studies for California waters suggest a value per day in the range of $25 to $35.[19] This range is consistent with that found by Walsh, et al. in a review of studies for freshwater fishing nationwide.[20] Therefore, we use the $25 to $35 range in estimating the value of freshwater fishing.

Exhibit 4-4

ESTIMATES OF CONSUMER SURPLUS PER FISHING DAY ($1996)

	Study	Location/Species	Consumer Surplus Estimate
Freshwater	Roach, 1996	American, Feather, Sacramento, and Yuba Rivers	$15.24 to $36.89; Preferred model specification yields $31.17-$36.37 estimate
	Hay, 1988	California bass anglers	$31.17
	Loomis and Cooper, 1990	Trout in Feather River	$26.69
	Walsh, 1988	Average of national studies	$30.85 to $40.08
Saltwater	NOAA, 1986	Marine fishing in Southern California	Charter: $29.74 to $66.24 Private: $82.46 to $100.02 Shore/Pier: $44.23 to $84.01
	Huppert, 1989	San Francisco Bay, salmon and striped bass	$70.88 to $357.36
	Walsh, 1988	Average of national studies	$94.89

[19] Roach (1996) applied a number of different model specifications to the same data. While lower values were obtained, the preferred model specifications yielded an estimate in the $30 to $35 range.

[20] Walsh, Richard G., Donn M. Johnson, and John R. McKean, *Review of Outdoor Recreation Economic Demand Studies with Nonmarket Benefit Estimates, 1968-1988*, December, 1988.

Estimates of consumer surplus per day of saltwater fishing vary more widely, depending upon the mode of fishing (charter boat, private boat, or shore fishing) and the species sought. Most of the results fall in the range of $50 to $100.[21] This range is consistent with the average value ($95 per day) reported by Walsh et al. for saltwater fishing. Therefore we use the range of $50 to $100 in estimating saltwater fishing value.

We can then develop a baseline value of recreational fishing on toxic-affected waters by multiplying the toxic-affected fishing days times the unit day value. For example, for lakes and reservoirs, 1.84 million toxic-affected fishing days times $25 to $35 day yields a total value of $46 to $64 million per year.

Potential Benefits

Using the baseline value of recreational fishing on toxics-affected waters, we can estimate the value of the improved experience associated with fishing these waters when toxic contamination is reduced to achieve water quality standards. As shown in Exhibit 4-3, for all waterbody types, application of Lyke's willingness to pay range (11 to 31 percent) yields a benefit estimate of between $9 and $35 million for freshwater and $15 and $84 million for saltwater. Overall, we estimate that the value of the improved fishing experience associated with meeting the toxic water quality criteria would be between $24 and $119 million per year.

Value of Increased Participation

In addition to decreasing the value of existing angling days, toxic pollution may also discourage participation in recreational fishing. Anglers may refrain from fishing because of concern that fish consumption is unsafe. In addition, since toxic contamination of surface waters occurs throughout the State, negative perceptions of water quality may exist Statewide, thereby reducing anglers' interest in fishing, regardless of concern that fish consumption is unsafe. A Statewide decrease in the level of toxics contamination on all waterbodies may improve perceptions of water quality, and thus have the benefit of restoring lost participation.

---

[21] While certain model specifications used by Huppert yielded high estimates (e.g., $344 per trip), these values represent outliers and apply specifically to two highly sought species (striped bass and chinook salmon) and therefore may not be broadly representative of saltwater fishing.

Estimating Increased Participation

We can value increased angling participation associated with achieving CTR water quality criteria by using the parameters discussed above for both baseline fishing days and mean consumer surplus per fishing day. We begin with the number of fishing days associated with toxics-impaired waters and the value of those fishing days. As discussed above, these parameters are derived from statewide participation figures and are scaled according the overall areal extent of toxics contamination as derived from the WQA database.

We then assume a range for the increase in participation that would result when toxic contaminants in California waters are reduced to meet the proposed criteria. The degree to which fishing days are reduced depends on two key factors. First, anglers must be aware of the contamination. While studies have shown that anglers are attentive to formal warnings and advisories (see below), they may be less attuned to lower-level toxics contamination in areas with no formal advisories. Second, the availability of substitute fishing areas plays a major role in how anglers respond to contamination. Specifically, if contamination affects a relatively limited area where substitutes are available, anglers will not reduce fishing effort, but will simply choose a new location.[22] The availability of substitutes will vary greatly depending upon geographic location and the economic status of the affected anglers. For example, poorer urban anglers fishing from piers in San Francisco Bay may be less able to simply change fishing location given the lack of equivalent substitutes and the practical constraints associated with traveling out of the city.

Most available studies focus on how toxics contamination affects fish consumption behavior rather than fishing effort. These studies are noteworthy because they provide a clear indication that angler behavior can be influenced by perceptions of toxic contamination, a key element in estimating reduced fishing days. For example, one study found that about half of the anglers who were aware of fish consumption warnings in Santa Monica Bay altered their consumption habits in some way.[23] This included nine percent of the anglers who stopped consuming fish altogether, although the study is unclear whether the elimination of fish consumption is associated with reduced fishing. Other behavior changes include reductions in the amount of fish consumed and changes in preparation and cooking methods.[24]

---

[22] This new location may require more extensive travel which in itself can reduce the consumer surplus the angler enjoys.

[23] *Santa Monica Bay Seafood Consumption Study -- September 1991 to August 1992*, prepared for Santa Monica Bay Restoration Project, prepared by MBC Applied Environmental Sciences, August 1993.

[24] Other studies show similar results. These include Udd, Edward and Joseph Fridgen, *Anglers' Perceptions of Toxic Chemicals in Rivers and Sport Fish*, paper presented at the National Wilderness Research Conference, July 1985; and Connelly, Nancy A., Barbara Knuth, and John Vena, *New York State Angler Cohort Study: Health Advisory Knowledge and Related Attitudes and Behavior; With a Focus on Lake Ontario*, September 1993.

Only a limited number of studies specifically consider the reduction in fishing days in a specific area due to water quality degradation. For example, a survey of New York State anglers found that of those who were aware of fishing advisories, 17 percent took fewer fishing trips.[25] In another study of lake recreation in Wisconsin, Caulkins, et al. estimated that the number of recreationalists using the site would increase by between 12 and 16 percent in response to general improvements in water quality.[26] Another study of acid rain contamination in New York's Adirondack region estimated recreational fishing losses associated with acidic deposition.[27] This study estimated a five percent decrease in angler days.

In addition, other EPA studies have used angler response to fishing advisories to justify a 20 percent reduction in fishing days in response to toxic pollution. For example, EPA's Regulatory Impact Analysis for the Metal Products and Machinery rule reduced the recreational fishing population by 20 percent in estimating benefits.[28] This assumption was based on studies conducted by Silverman (1990), West et al. (1989), and Connelly et al. (1993).

Toxic water contamination in California ranges in nature, from extensive pollution that results in fishing advisories in estuaries, rivers, and lakes, to more limited pollution that may likely go unknown or unheeded by many anglers. While all of the studies reviewed above indicate that anglers change behavior significantly in the face of extensive contamination, it is less clear what the effect of more limited toxic contamination would be. Therefore, in light of this uncertainty, we apply a range of estimates to derive the increase in fishing days that might occur if the CTR criteria are met. In the upper bound, we use 20 percent, a figure consistent with evidence from fishing advisory studies. This upper bound is applicable because many key fishing areas located near large population centers currently have fishing advisories in effect, including San Francisco Bay,

---

[25] Connelly, Nancy A., Tommy Brown, and Barbara Knuth, *New York Statewide Angler Survey*, 1988, p. 111.

[26] Caulkins, Peter P., Richard Bishop, Nicolas Bouwes, "The Travel Cost Model for Lake Recreation: A Comparison of Two Methods for Incorporating Site Quality and Substitution Effects," *American Journal of Agricultural Economics*, May, 1986.

[27] Mullen, John K. and Fredric Menz, "The Effect of Acidification Damages on the Economic Value of the Adirondack Fishery to New York Anglers," *American Journal of Agricultural Economics*, February, 1985.

[28] U.S. EPA, Office of Science and Technology, *Regulatory Impact Assessment of Proposed Effluent Guidelines and Standards for the Metal Products and Machinery Industry (Phase I)*, April, 1995.

Los Angeles/Long Beach Harbor, and the area around the Kesterson National Wildlife Refuge. In the lower bound, we use five percent, a figure intended to reflect the increase in participation that would occur on waters with minor to moderate toxics contamination.

Potential Benefits

Exhibit 4-5 presents estimates of the value of potential increased angling participation. As shown, we multiply the number of toxics-affected fishing days by the value of these days (estimated in the previous section and shown in Exhibit 4-3) to derive the total value of toxics-affected fishing days. We then multiply this value by five percent and 20 percent to estimate the value of the expected increase in angling participation attributable to meeting the CTR criteria. As the exhibit shows, we estimate a lower bound annual benefit of $11 million and an upper bound benefit of $77 million. *When these values associated with increased participation are added to the benefits of improved experience, we estimate a range of $35 million to $196 million of total use-value benefits associated with recreational fishing.*

Uncertainties

There are several limitations and uncertainties associated with this analysis of potential recreational fishing benefits. First, as with any benefits transfer, we assume that the willingness to pay to fish in cleaner waters (expressed by respondents in the Lyke survey) is representative of the range of values that California anglers would place on a "contaminant free" fishery. Currently, we have no information to indicate that California behavior would be significantly different than that reported by Lyke for the Midwest. However, the Lyke study addressed an impaired area of Lake Michigan where several fishing advisories had been issued. In contrast, many of the California waters classified as impaired may be less contaminated than the waters in the Lyke study. To the extent that this is true, we may overstate benefits by using the Lyke willingness to pay range.

Second, we assume that reducing toxic discharges to meet toxic water quality criteria is approximately equivalent to achieving a "contaminant free" fishery. Further, we assume that reducing contamination to meet water quality criteria should apply to both ambient water quality criteria for aquatic life (both chronic and acute) as well as ambient water quality criteria levels for human health. Currently we have no information to indicate that this would not be a reasonable assumption to make for this analysis. If this assumption is incorrect, however, then our benefit estimates may be overstated.

Exhibit 4-5

RECREATIONAL FISHING: POTENTIAL ANNUAL BENEFITS OF INCREASED PARTICIPATION

FRESHWATER FISHING	Total Value of Toxics-Affected Fishing Days		Lower Bound Percent Increase In Participation	Upper Bound Percent Increase In Participation	Lower Bound Benefit of Increased Participation	Upper Bound Benefit of Increased Participation
	Lower Bound	Upper Bound				
Lakes and Reservoirs	$45,974,300	$64,364,020	5%	20%	$2,298,715	$12,872,804
Ponds	$7,286,975	$10,201,765	5%	20%	$364,349	$2,040,353
Rivers and Streams	$28,513,775	$39,919,285	5%	20%	$1,425,689	$7,983,857
Subtotal:	$81,775,050	$114,485,070			$4,088,753	$22,897,014
SALTWATER FISHING						
Bays						
-- San Francisco Bay	$26,737,500	$53,475,000	5%	20%	$1,336,875	$10,695,000
-- Other California Bays	$50,345,925	$100,691,850	5%	20%	$2,517,296	$20,138,370
Estuaries	$38,765,835	$77,531,670	5%	20%	$1,938,292	$15,506,334
Saline Lakes	$18,970,515	$37,941,030	5%	20%	$948,526	$7,588,206
Subtotal:	$134,819,775	$269,639,550			$6,740,989	$53,927,910
TOTAL	$216,594,825	$384,124,620			$10,829,741	$76,824,924

Source: EPA analysis

Third, by scaling according to the areal extent of toxic pollution, we implicitly assume that anglers are somewhat evenly distributed to all surface water bodies. In fact, anglers may be free to relocate away from water bodies affected by toxics and fish in cleaner areas. If this is the case, then our benefit estimates could be overstated. Alternatively, fishing effort may be disproportionately concentrated on impaired waters (including those with fish consumption advisories) because of the proximity of the waters to population centers (e.g., San Francisco Bay, Los Angeles Harbor, Lake Herman, Santa Clara County Lakes, and the Grassland Area/Kesterson National Wildlife Refuge). This would lead us to understate benefits. Because we have not done a waterbody-by-waterbody evaluation of substitute fishing areas and angler substitution behavior, we cannot estimate the direction or degree of bias in our estimates.

Fourth, we assume that the condition of assessed waters in California is representative of conditions in all unassessed resources. If conditions are considerably worse or better in these unassessed waters, then benefit estimates are likely to be higher or lower than those presented here. As described in greater detail in Chapter 2, although the WQA provides water quality assessments for only nine percent of California's total stream and river miles, and approximately 50 percent of wetlands, the majority of State total lake and reservoir acreage has been assessed. Further, water quality analysts in EPA believe that nearly all the bays/estuaries and saline lakes in the State have been well characterized, monitored, or otherwise evaluated for toxic contamination. Although the consensus of the U.S. EPA and State experts was that some of the assumptions used here may have created a bias toward overestimating toxics contamination Statewide, they also stated that certain other assumptions used in the analysis may have created a bias in *underestimating* the extent of toxics contamination. For example, we assume that the type and scope of all toxics of concern in all State waters appear in the WQA data base. However, this may underestimate the extent of toxics impairment because of the infrequency of ambient monitoring throughout the State or because of the difficulty of detecting the ambient concentrations of certain toxic pollutants when their water quality criteria are below minimum detection limits. Consequently, because of all of the uncertainties associated with the WQA data base, State of California and U.S. EPA experts advised against an attempt to quantitatively estimate the magnitude of the bias in either direction.

Fifth, this analysis assumes that anglers are aware of toxic contamination beyond waters that have fish consumption advisories, and that their angling behavior is affected. To the extent that anglers are unaware of the presence of toxic pollutants, or that they are aware and don't change how often and where they fish, their fishing experience is not diminished. If this is the case, then this analysis may overstate the benefits associated with meeting toxics water quality criteria.

Finally, the persistence and toxicity of the pollutants covered by the criteria have important implications for all parts of the benefits analysis. Because some of these compounds (e.g., PCBs, dioxins, mercury) may persist in various waters, sediment, and animal tissue for years after point and non-point source toxic discharges have been eliminated, a portion of the benefits described here may not be realized immediately.

In addition to use values, the total value of an aquatic system also includes values that individuals hold for the resource unrelated to their current use of goods and services provided by the resource. Individuals may value the existence of the aquatic system or the availability of the goods and services provided by the system, even if they do not use the goods and services themselves. Non-use values may also stem from the desire to preserve the resource for future generations (bequest value) or from a philanthropic sense of environmental responsibility. Reducing toxic contamination to meet the toxic water quality criteria is expected to increase these non-use values.

Relationship Between Use and Non-Use Values

Non-use values can be estimated roughly by considering the relationship between the use value and non-use value of a resource. While the non-use values of a resource need not be directly related to use value, such a comparison provides a simple rule-of-thumb for developing approximate measures of non-use values.

Application of this approach requires two key inputs: (1) an estimate of use values; and (2) an estimate of the typical ratio of non-use value to use value. The first input is based on the use values derived previously for recreational fishing: from $35 million per year to $196 million per year. To estimate the ratio of non-use to use values, we rely on a literature search performed for a previous EPA study.[29] Based on five studies of water resources, this literature search yielded a range of approximately 0.5 to 2.0 in the ratio of non-use values to use values. The studies are summarized in Exhibit 4-6 below. Past EPA studies have relied on the lower end of this range (i.e., 0.5, meaning that passive use values are equal to 50 percent of use values).[30] The mathematical average of the studies shown in Exhibit 4-6 is approximately 1.5. Therefore, we use the range of 0.5 to 1.5, implying that passive use values are equal to between 50 and 150 percent of use values.

Potential Benefits

To estimate non-use benefits, we apply the range of non-use to use value ratios discussed above (0.5 to 1.5) to the previously estimated range of recreational angling use values (both the value of the improved fishing experience and the value of increased participation, roughly $35 to $196

---

[29] U.S. EPA Office of Pollution Prevention and Toxics, *Ecological Benefits Assessment Model: Documentation Manual*, May, 1997.

[30] For example, see U.S. EPA Office of Water, *Regulatory Impact Analysis of the Final Great Lakes Water Quality Guidance, Final Report*, March 1995.

Exhibit 4-6

ESTIMATES OF THE RATIO OF NON-USE VALUE TO USE VALUE FOR STUDIES OF WATER RESOURCES

Authors (Date)	Study Location	Description of Good Valued in the Study	Ratio of Ecological and Passive Use Value to Use Value
Dornbusch and Falcke (1974)	Communities along seven U.S. water bodies	Survey of property owners on important of attributes of water quality improvement	0.75 to 2.03[1]
Greenley, Walsh and Young (1981)[2]	Denver and Fort Collins, Colorado	Preservation and improvement of water quality of South Platte River Basin	0.46 to 0.84[3]
Walsh, Loomis and Gilman (1984)[2]	Colorado	Value for protection of additional 1.2 to 10 million acres of Colorado wilderness	0.55 to 0.97
Sutherland and Walsh (1985)[2]	Montana	Value of protecting water quality at Flathead Lake and River	2.56
Sanders, Walsh and Loomis (1990)[2]	Colorado	Value of increasing protection of Colorado Rivers	1.88

1. Ratios vary depending on whether aesthetic value is considered as part of use or passive use value.

2. These studies used the contingent valuation method. All four studies asked respondents to first state their total value for the good in question, and in subsequent questions asked respondents to allocate this total to recreation use, option value, existence value and bequest value. In all cases, the wording of the question describing option value focused on the value of potential future use (i.e., option price). For the purposes of estimating the ratio of use to non-use value, we have included option price in use value.

3. This range reflects the results of two payment scenarios considered in the survey (increase in water bill or sales tax) and comparisons of use value to passive use value held by users and use value to passive use values held by non-users.

million). This approach yields an estimate of non-use benefits of between $17 million and $294 million. It is important to note that we have only monetized estimates of recreational fishing benefits associated with meeting toxic water quality criteria, even though other use benefit values such as recreational hunting, wildlife viewing, and commercial use are expected to be significant, but have not been quantified or monetized for the aquatic life criteria.[31] Consequently, the benefits presented here likely understate the total non-use benefits likely to accrue when toxic discharges from all sources are reduced to meet CTR water quality criteria.

There are several limitations involved in using this approach. First, the studies from which these ratios were derived did not explicitly consider ecological values, but only asked respondents about existence and bequest value. It is difficult to determine the extent to which respondents may have incorporated ecological values into their responses, however. For example, when thinking about existence value, individuals may consider the wildlife habitat provided by a distant harbor, but may not explicitly consider objectives such as biodiversity. Overall, it is difficult to know the extent to which ecological non-use values drive the responses to contingent valuation surveys.

Second, contingent valuation is the only method available to evaluate non-use values of a resource. Use of this method, however, is controversial because it measures attitudes and not behavior, and therefore is subject to the uncertainties inherent in any survey-based research; i.e., it may over- or understate actual values, depending upon the quality of the survey instrument, the incentives of the respondents, and other factors. As a result, significant debate exists over whether contingent valuation can yield reliable results.[32] NOAA has proposed guidelines for contingent valuation studies for use in natural resource damage assessment.[33] While some of the contingent valuation studies summarized in Exhibit 4-6 meet some of the guidelines, none meet *all* of these proposed guidelines. While guidelines for policy analysis studies may differ somewhat from NOAA's guidelines for damage assessments, the cited studies did not use state-of-the-art approaches, which may reduce the reliability of the resulting estimates.

---

[31] For example, the U.S. Fish and Wildlife Service recommends a 2 ug/l selenium standard for protecting aquatic-dependent wildlife species. The economic benefits of a selenium wildlife criterion are reviewed in U.S. EPA, *Potential Benefits of a Selenium Wildlife Water Quality Criterion in California*, June 1997.

[32] See Mitchell, R.C., and R.T. Carson, *Using Surveys to Value Public Goods: The Contingent Valuation Method*, Washington DC, Resources for the Future, 1989.

[33] U.S. Department of Commerce, National Oceanic and Atmospheric Administration, 15 CFR Part 990, Natural Resource Damage Assessments: Proposed Rules, 59 FR 1062, 1994.

HUMAN HEALTH BENEFITS

As previously described in Chapter 3, the bioaccumulation of toxic pollutants in aquatic life and water-dependant wildlife can pose a significant health risk to those who eat fish and waterfowl. This is particularly true for recreational or subsistence anglers, who tend to consume greater quantities of wildlife than the average person and may catch fish from areas that are highly contaminated. A potential post-rule benefit is a likely reduction in the concentration of pollutants in fish and waterfowl tissue, with a resulting decrease in risk to recreational/subsistence anglers and waterfowl hunters.

We quantified health benefits for recreational anglers in Chapter 3 by comparing risks from the consumption of fish under baseline conditions to those that would prevail once California implements water quality programs to achieve the criteria. Results of the analysis include:

- The cancer population risk for freshwater anglers throughout the State would decrease by between 5 and 10 cases per year (5 to 11 cases under baseline conditions to zero to one cases post-compliance). For San Francisco Bay anglers, population risk would decrease by less than one case per year.

- Individual cancer risks for the 2.2 million California freshwater anglers and 125,000 San Francisco Bay anglers would be reduced by 91 percent.

- The non-cancer hazard index is reduced by 67 percent for freshwater anglers. The hazard index for freshwater anglers would decrease from 2.4 to less than 0.8 at the median consumption level.

- The non-cancer hazard index for San Francisco Bay anglers is reduced by 76 percent. The hazard index would decrease from 3.6 to less than 0.9 at the median consumption level.

- It is possible that a small subset of California anglers (Middle Eastern, Samoan and Cambodian) are at greater risks because of higher consumption rates. Asian and Hispanic anglers face disproportionately higher risks due to the consumption of whole fish.

- Risks to subsistence anglers have not been estimated, but are likely to be somewhat higher than risks to anglers because of their higher levels of fish consumption.

- We were not able to estimate cancer or non-cancer health risks associated with consuming contaminated waterfowl.

We estimated a monetary value of benefits to society from avoided cancer cases associated with consuming contaminated fish, based on a methodology developed and explained in more detail in the RIA of the Proposed Effluent Limitations Guidelines and Standards for the Metal Products and Machinery Industry (MP&M).[34] The valuation of benefits is based on estimates of society's willingness-to-pay to avoid the risk of cancer-related premature mortality. Although it is not certain that all cancer cases will result in death, to develop a worst case estimate for this analysis, avoided cancer cases are valued on the basis of avoided mortality. To value mortality, we used the range of values -- approximately $2 million to $10 million per case -- developed and applied in other studies such as the RIAs for the MP&M effluent guidelines and the Great Lakes Water Quality Guidance.

To derive the benefits associated with reducing the incidence of cancer from consumption of contaminated fish, we multiply total cancer cases (5 to 11) times the range of $2 million to $10 million per case to derive a total monetized benefit of $10 to $110 million.

We were unable to value decreased incidence of non-cancer illness. Non-cancer illnesses include reproductive, neurological, immunological, and circulatory problems. Little data are available regarding both dose-response relationships for non-cancer outcomes and the monetary value of avoiding such outcomes.[35] Because we were not able to evaluate the monetized value of decreased incidence of non-cancer disease, our economic benefit estimates likely understate the range of total health-related economic benefits associated with this rule.

OTHER BENEFITS NOT QUANTIFIED

Reducing toxic contamination of aquatic systems to meet the proposed water quality criteria will likely yield other benefits that we were unable to quantify or monetize. Therefore, our quantitative estimates of benefits probably understate total benefits. These unmonetized benefit categories are briefly summarized below.

---

[34] U.S. EPA, April 1995.

[35] Cannon, Matt, Raymond Kopp, and Alan Krupnick, *Valuation of Developmental and Reproductive Effects: A Scoping Study*, October 1996.

Drinking Water Treatment Savings

Reducing toxics discharges from all sources to meet water quality criteria may reduce the degree of treatment needed to bring surface water sources into compliance with drinking water standards. For instance, if supplies drawn from ambient waters are treated to remove toxic contaminants before they are ingested, or contaminated sources are abandoned when they fail to meet (or cannot be treated efficiently to meet) drinking water standards, then improvement of ambient water quality to meet the criteria would reduce the cost of treatment or avoid the cost of switching to alternative water supplies. Drinking water treatment savings might be especially large when the criterion for a pollutant is more stringent than the maximum contaminant level (MCL) permitted for the pollutant under the Safe Drinking Water Act. Chemicals for which the aquatic life standard is more stringent than the human health standard for drinking water include the metals cadmium, chromium, copper, lead, mercury, nickel, silver, and zinc. Although we have not quantified or monetized these potential cost savings, they could be significant.

Sludge Treatment Savings

Reducing toxic contamination of surface waters to meet water quality criteria may generate sludge treatment savings if toxic contaminants are reduced prior to entering publicly or privately owned sewage treatment plants (POTWs). As a result of reducing toxic pollution in the sewage sludge, POTWs may be able to meet more stringent limits, which, in turn, may permit less expensive use or disposal of the sewage sludge. In the best case, sewage sludge will meet land application pollutant concentration limits. This sewage sludge may be disposed of via land application, which in some instances, may be substantially less costly than other use or disposal practices such as incineration or land-filling.[36] Because of time and budget constraints, we were not able to estimate this benefit for POTWs throughout California, but we expect that sludge treatment cost savings might be substantial if toxics are reduced via pollution prevention (e.g., prior to arriving at the POTW).

Dredging and Navigation

Toxic contaminants discharged to surface water may settle to sediment and remain there for decades if the pollutants are persistent (e.g., metals such as mercury, complex organics). Previous studies have demonstrated how dredging costs increase greatly when sediment contamination is

[36] For a more detailed description of this potential benefit, see Chapter 11 of the MP&M Effluent Guideline RIA, 1995.

present.[37] Most of this increased cost is attributable to proper disposal of the contaminated sediment. Reducing loadings of toxic pollutants to sediments to achieve water quality criteria may ultimately reduce sediment contamination in California waters, thereby reducing dredged material management costs.

Commercial Fishing and Shell Fishing

Commercial fishing and shell fishing are major economic activities in the State of California. In 1991 the value of the statewide commercial fishery catch totaled approximately $134.8 million, which was below historical levels.[38] The decline in commercial fisheries values is largely attributable to harvest declines rather than decreasing fish prices. Toxics contamination of water, sediments and fish tissue can lead to harvest restrictions and bans, and also can adversely affect the survival, abundance and biomass of the fisheries population, consequently reducing the economic value of the fishery. Reducing toxics loadings to meet water quality criteria may contribute to the overall improvement of the health and abundance of fish populations, and therefore will increase the economic value of the harvest. Further, reduced toxics loadings could result in reduced contamination of fish tissue, possibly reducing cancer and non-cancer illness incidence associated with consumption of contaminated fish. Because of data and time limitations, we have not estimated the economic or health implications for California fisheries of reducing toxics contamination to meet water quality criteria. However, we believe such benefits could be significant.

Avoided Cost of Endangered Species Management and Associated Land Use Restrictions

The avoided costs of managing State and Federal Threatened and Endangered species and the costs associated with attendant land use restrictions are a potential benefit of the toxics rule. California has the greatest number of T&E species of any state (see Chapter 5 for a more detailed discussion of T&E species). Currently, USFWS spends several million dollars per year in California managing T&E species, including preparing species-specific listings, recovery plans, etc. These listings and recovery plans describe species-specific management actions that are necessary to avoid

---

[37] National Oceanic and Atmospheric Administration, *Summary of Potential Economic Damages to the Resources of Lavaca Bay and Matagorda Bay Texas as Result of Mercury Contamination*, May 1991.

[38] U.S. EPA, *Regulatory Impact Assessment of the Final Water Quality Standards for the San Francisco Bay/Delta and Critical Habitat Requirements for the Delta Smelt*, Region 9, (December), 1994.

species extinction. For instance, exposure to toxic water contaminants[39] has been identified as one of several factors together with habitat destruction, to be considered in the recovery of the Federal Endangered California Clapper Rail, which occurs only in South San Francisco and Suisun Bay. Some of the management plans may lead to establishment of numerous new and complex requirements on land use. For instance, listing of a species associated with a river, stream or estuary may severely restrict water management, adjacent agricultural activities, or development of the species' habitat. Reducing toxics to meet the proposed water quality criteria may enhance and contribute to the overall recovery of certain listed species, may help to prevent future listings of certain species, and may result in significant avoided costs associated with T&E management plans.

Property Value Impacts

Knowledge of toxics contamination may lead to reductions in the value of properties surrounding surface water bodies.[40] The results of a 1988 property value study in San Francisco Bay suggest that this benefit could exist for the large population centers surrounding toxics-impaired bays (e.g., San Francisco, Los Angeles, Santa Monica).[41] The San Francisco study concluded that the marginal implicit price of proximity to water for residential property was significantly greater in areas of San Francisco Bay where the condition of the water was better. The marginal implicit price of this difference in water condition was estimated to be approximately $41,000 (1985$) in absolute terms, or approximately 11 percent of the value of a waterfront property in relative terms.

Because the study did not estimate the individual contribution that the different water quality constituents (e.g. toxics, oxygen, floatables, odor) made to overall water quality in the areas evaluated, it is not possible to estimate what percentage of the 11 percent property value increase was due to toxic pollutants covered by this rule. The results of this study indicate however, that increased property values could be significant statewide if loadings of toxic constituents from all sources were reduced to meet proposed water quality criteria.

---

[39] Clapper Rail eggs have been found to harbor elevated levels of mercury, selenium, and other contaminants.

[40] Mendelsohn, Robert, Daniel Hellerstein, Michael Huguenin, Robert Unsworth, and Richard Brazee, "Measuring Hazardous Waste Damages with Panel Models," *Journal of Environmental Economics and Management*, Vol. 22, No. 3, 1992.

[41] D. Kirshner and Deborah Moore, "The Effect of San Francisco Bay Water Quality on Adjacent Property Values," *Journal of Environmental Management* (1989) 27:263-274.S.

Ecological Benefits

Achievement of the water quality criteria established by the CTR may enhance a variety of ecological services provided by aquatic systems. While it is beyond the scope of this study to monetize these services, it is important to note that society may place significant value on them. Relevant ecological benefits that may accrue include reduced mortality/morbidity to aquatic and terrestrial wildlife, improved habitat supporting fish spawning and migration, improved habitat supporting threatened and endangered species, and avoidance of the cost of endangered species management and associated land use restrictions. We characterize several of these benefits more fully in Chapter 5 of this report.

REFERENCES

Caulkins, Peter P., Richard Bishop, Nicolas Bouwes, "The Travel Cost Model for Lake Recreation: A Comparison of Two Methods for Incorporating Site Quality and Substitution Effects," *American Journal of Agricultural Economics*, May, 1986.

Connelly, Nancy A., Barbara Knuth, and John Vena, *New York State Angler Cohort Study: Health Advisory Knowledge and Related Attitudes and Behavior, With a Focus on Lake Ontario*, September 1993.

Connelly, Nancy A., Tommy Brown, and Barbara Knuth, *New York Statewide Angler Survey*, 1988.

Costanza, Robert, et al., "The Value of the World's Ecosystem Services and Natural Capital," *Nature*, May 15, 1997.

Daily, Gretchen, editor, *Nature's Services: Societal Dependence on Natural Ecosystems*, Island Press, 1997.

Hay, Michael J., *Analysis of the 1985 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation, U.S. Department of the Interior Report 85-1, Net Economic Values for Deer, Elk, and Waterfowl Hunting and Bass Fishing*, 1988.

Huppert, Daniel D., "Measuring the Value of Fish to Anglers: Application to Central California Anadramous Species," *Marine Resource Economics*, Vol. 6, pp. 89-107, 1989.

Kirshner, D., and Deborah Moore, "The Effects of San Francisco Bay Water Quality on Adjacent Property Values," *Journal of Environmental Management* (1989) 27:263-274.S.

Loomis, John and Joseph Cooper, "Economic Benefits of Instream Flow to Fisheries: A Case Study of California's Feather River," *Rivers*, January, 1990, pp. 23-30.

Lyke, "Discrete Choice Models to Value Changes in Environmental Quality: A Great Lakes Case Study," Dissertation submitted to the Graduate School of the University of Wisconsin-Madison, 1993.

MBC Applied Environmental Sciences, *Santa Monica Bay Seafood Consumption Study -- September 1991 to August 1992*, prepared for Santa Monica Bay Restoration Project, August 1993.

REFERENCES
(continued)

Mendelsohn, Robert, Daniel Hellerstein, Michael Huguenin, Robert Unsworth, and Richard Brazee, "Measuring Hazardous Waste Damages with Panel Models," *Journal of Environmental Economics and Management*, Vol. 22, No. 3, 1992.

Mitchell, R.C., and R.T. Carson, *Using Surveys to Value Public Goods: The Contingent Valuation Method*, Washington DC, Resources for the Future, 1989.

Mullen, John K. and Fredric Menz, "The Effect of Acidification Damages on the Economic Value of the Adirondack Fishery to New York Anglers," *American Journal of Agricultural Economics*, February, 1985.

National Oceanic and Atmospheric Administration, *Summary of Potential Economic Damages to the Resources of Lavaca Bay and Matagorda Bay Texas as Result of Mercury Contamination*, May 1991.

Roach, Brian, *Angler Benefits Along Four California Rivers: An Application of Tobit Analysis*, March 1996.

Setzler-Hamilton, Eileen, et al., "Striped Bass Populations in Chesapeake and San Francisco Bays: Two Environmentally Impacted Estuaries," *Marine Pollution Bulletin*, Vol. 19, No. 9, pp. 466-477.

Silverman, W., *Michigan's Sport Fish Consumption Advisory: A Study in Risk Communication*, thesis submitted in partial fulfillment of the requirements for the degree of Master of Science (Natural Resources) at the University of Michigan, May 1990.

U.S. Department of Commerce, National Oceanic and Atmospheric Administration, 15 CFR, Part 990, Natural Resource Damage Assessments: Proposed Rules, 59 FR 1062, 1994.

U.S. EPA, *Ecological Benefits Assessment Framework*, draft, prepared for EPA Social Sciences Discussion Group, EPA Science and Policy Council, 1996.

U.S. EPA, Office of Science and Technology, *Regulatory Impact Assessment of Proposed Effluent Guidelines and Standards for the Metal Products and Machinery Industry (Phase I)*, April, 1995.

REFERENCES
(continued)

U.S. EPA, Office of Pollution Prevention and Toxics, *Ecological Benefits Assessment Model: Documentation Manual*, May, 1997.

U.S. EPA, *A Brief Overview of Natural Resource Valuation Issues and Methodologies*, Office of Policy, Planning and Evaluation, 1994.

U.S. EPA Office of Water, *Regulatory Impact Analysis of the Proposed Great Lakes Water Quality Guidance, Final Report*, March 1995.

U.S. EPA, *Regulatory Impact Assessment of the Final Water Quality Standards for the San Francisco Bay/Delta and Critical Habitat Requirements for the Delta Smelt*, Region 9, (December), 1994.

U.S. Fish and Wildlife Service, *National Survey of Fishing, Hunting, and Wildlife-Associated Recreation -- California*, July 1993.

Udd, Edward and Joseph Fridgen, *Anglers' Perceptions of Toxic Chemicals in Rivers and Sport Fish*, paper presented at the National Wilderness Research Conference, July 1985.

Walsh, Richard G., Donn M. Johnson, and John R. McKean, *Review of Outdoor Recreation Economic Demand Studies with Nonmarket Benefit Estimates, 1968-1988*, December, 1988.

West, P., et al., *Michigan Sport Anglers Fish Consumption Survey: A Report to the Michigan Toxic Substances Control Commission*, University of Michigan School of Natural Resources, Technical Report #1, May 1989.

ECOLOGICAL BENEFITS CHAPTER 5

INTRODUCTION

California is one of the most biologically diverse areas in the world. Within its 160,000 square miles of land, and hundreds of thousands of acres and miles of water resources, California harbors more unique plants and animals than any other state in the nation. The diversity of climates, landscapes, and habitats, and all the barriers to migrations such as mountains and deserts, have led over thousands of years to the evolution of a large number of unique species and varieties of plants and animals, many of which are found only in California.[1] For example, there are 46 species of amphibians, 96 species of reptiles, 563 species of birds, 190 species of mammals, 8,000 species of plants and 30,000 species of insects recorded in the State. The 63 types of freshwater fish are unique in that a high percent of them are found only in California.[2] Many of these species exist in or are dependent upon aquatic ecosystems during all or a part of their lives, and consequently may be adversely affected by toxic discharges to surface waters.

The purpose of this chapter is to describe the potential ecological benefits expected to occur when toxic pollutant discharges are reduced to meet the water quality criteria proposed in the California Toxics Rule (CTR). As described in the previous chapter on economic benefits, the standard approaches used to evaluate environmental and ecological benefits are entirely anthropocentric. Improving the survival, growth, productivity, and reproductive capacity of aquatic and terrestrial organisms, populations and communities has worth above and beyond the direct

[1] Steinhart, 1994.

[2] Moyle, 1994.

consumptive use of selected species for recreation, commercial, and other purposes. Economic valuation methods become more and more difficult to use to evaluate ecological benefits as the ecosystem services in question become more complex, large-scale, interconnected, and subtle. The complexity of ecosystems, our limited ability to predict ecosystem-level responses to toxics, and difficulties in assessing causal linkages between the current levels of toxics in California waters and associated ecological impacts makes the determination of ecological and economic benefits very difficult. Furthermore, economic valuations cannot entirely capture the full range of benefits associated with protecting and/or restoring the function, structure, and composition of ecosystems. The goal of this chapter (and Chapter 6) therefore, is to characterize the range of ecological effects and impacts associated with specific toxic pollutants discharged to California's aquatic ecosystems, and to describe some of the organism, population, and community benefits that are expected to be associated with reducing these discharges to meet water quality criteria, independent of their direct monetary value to humans.

Key Findings

The ecological benefits expected to accrue when toxic contaminants are reduced to levels that meet chronic and acute criteria in all California waters are significant. As shown in Exhibit 5-1, large areas of ecological resources in every region of the state currently experience impairment of water quality (and by extension, the resources they support) by such toxics as metals, selenium, pesticides, and priority organics (see Figure 5-1 for the location of the nine regions cited). Reducing loadings of these contaminants to meet criteria levels is expected to lead to healthier and more stable organisms, populations, and communities in ecosystems that exist in or are dependant on more than 800,000 acres of assessed bays, estuaries, lakes, and wetlands and more than 3,700 miles of rivers that are now currently impaired by toxic pollutants. Other specific ecological benefits expected to result from implementation of this rule include the following:

- Reductions in toxics loadings are expected to contribute to improved conditions for fish spawning and/or migration in more than 223,000 acres of bays/harbors and estuaries, 102,000 acres of lakes, 1,000 miles of rivers and streams, and 11,000 acres of saline lakes.

- Potential bioaccumulatives of concern that currently threaten fish and wildlife throughout the State include selenium, mercury, PCBs, dioxins, and chlorinated pesticides. Mercury concentrations in California fish are estimated to reach levels that may be hazardous to piscivorous wildlife. [3] Adverse effects on wildlife are also occurring as a result of exposure to selenium. Populations that may widely benefit from reduced concentrations

[3] Piscivorous wildlife are birds, fish, and mammals that eat fish.

Exhibit 5-1

SUMMARY OF BASELINE CALIFORNIA REGIONAL WATER QUALITY ASSESSMENTS

Region	Areal Extent of Toxics Impairment	Pollutants of Concern	Primary Pollutant Sources	Key Waterbodies Impaired	Ecological Resources Potentially Affected
Region 1: North Coast Region	55% of bays (16,500 acres); minor impairment of other waterbodies	Metals, pesticides	Mix of point sources (municipal and industrial effluent) and nonpoint sources (agriculture and urban runoff)	Arcata Bay, Humboldt Bay	Wildlife habitat; fish spawning and migration; rare and endangered species
Region 2: San Francisco Bay	Large areas impaired by toxics, including 70% of bays (200,000 acres);60% of wetlands (57,000 acres); 39% of rivers (244 miles); 172,000 acres impaired supporting fish spawning/migration and rare and endangered species	Metals, trace elements, priority organics	Urban runoff and other nonpoint sources affect largest areas; some impairment from municipal and industrial point sources	San Francisco Bay (Lower, Central, South), Suisun Marsh	Wildlife habitat; fish spawning and migration; rare and endangered species; waterfowl; piscivorous wildlife in San Francisco Bay, Lake Herman, Guadalupe Reservoir, and others species
Region 3: Central Coast Region	47% of lakes (11,700 acres);36% of estuaries (1,700 acres); minor impairment of rivers and bays	Metals, pesticides	Agriculture, mining, unspecified nonpoint sources	Morro Bay, Carpinteria Marsh, Elkhorn Slough	Wildlife habitat; fish migration and spawning; rare and endangered species; piscivorous wildlife in Nacimiento River
Region 4: Los Angeles Basin	Over 90% of bays and estuaries impaired (16,000 acres); minor impairment of rivers and lakes	Pesticides, priority organics, trace elements	Mix of point sources (municipal treatment, "other" point sources) and nonpoint sources (agriculture, hydrological modification, and urban runoff)	Mugu Lagoon, San Gabriel River (lower), Los Angeles River (upper)	Wildlife habitat; fish migration and spawning; rare and endangered species; piscivorous wildlife in Lake Nacimiento and Los Angeles Harbor

Exhibit 5-1

SUMMARY OF BASELINE CALIFORNIA REGIONAL WATER QUALITY ASSESSMENTS

Region	Areal Extent of Toxics Impairment	Pollutants of Concern	Primary Pollutant Sources	Key Waterbodies Impaired	Ecological Resources Potentially Affected
Region 5: Central Valley Region	Large areas impaired by toxics, including 100% of estuaries (48,000 acres); 23% of lakes (120,000 acres); 21% of rivers (1,200 miles); 48,000 acres of Delta waterways impaired for fish spawning/migration and rare and endangered species	Metals, trace elements	Agriculture, mining; smaller areas affected by municipal treatment, urban runoff, storm sewers, and other nonpoint sources	Delta Waterways, Clear Lake, American River, Feather River, Sacramento River, Grasslands Marshes, Shasta Lake	Wildlife habitat; fish spawning and migration; rare and endangered species; piscivorous wildlife in Clear Lake, Lake Berryessa, and Grasslands Area; waterfowl in Grasslands Area
Region 6: Lahontan Region	34% of saline lakes (66,000 acres); 19% of lakes (36,000 acres); 13% of rivers (372 miles)	Metals, trace elements, priority organics	Naturally occurring levels of metals and trace elements; lesser areas affected by agriculture, land development, and mining	Eagle Lake, Owens River, Truckee River, Honey Lake	Wildlife habitat; fish spawning and migration; rare and endangered species
Region 7: Colorado River Basin	60% of rivers (1,400 miles) impaired; 220,000 acres of saline lake (Salton Sea) supporting rare and endangered species and wildlife	Pesticides, trace elements	Agriculture	Salton Sea	Wildlife habitat; rare and endangered species. piscivorous wildlife and waterfowl in Salton Sea
Region 8: Santa Ana River Basin	Over 90% of bays and estuaries impaired (4,000 acres); 27% of lakes (4,000 acres)	Metals, pesticides	Primarily nonpoint sources including agriculture, urban runoff, and land development	Upper Newport Bay	Wildlife habitat; fish spawning and migration; rare and endangered species

Exhibit 5-1

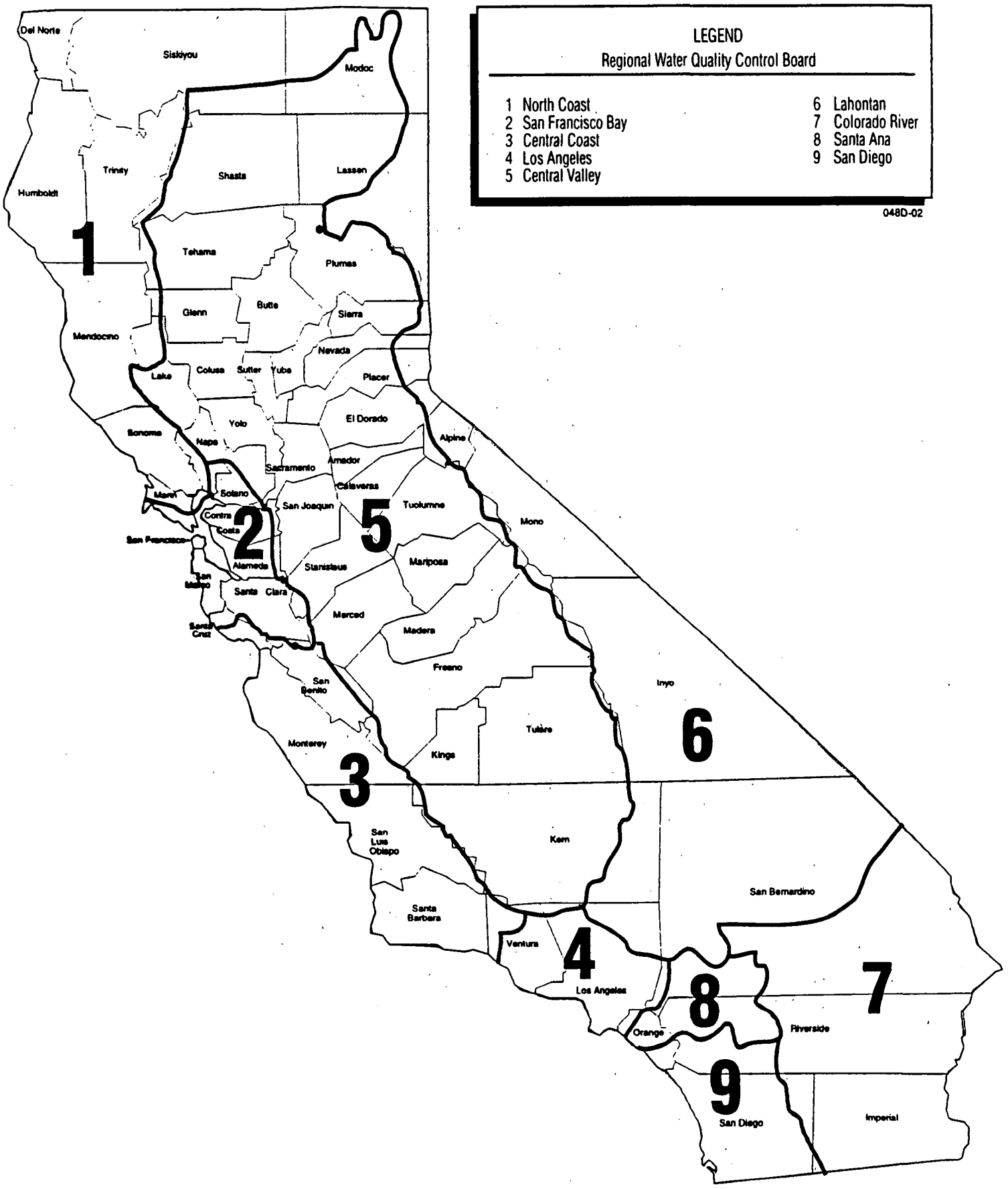
SUMMARY OF BASELINE CALIFORNIA REGIONAL WATER QUALITY ASSESSMENTS

Region	Areal Extent of Toxics Impairment	Pollutants of Concern	Primary Pollutant Sources	Key Waterbodies Impaired	Ecological Resources Potentially Affected
Region 9: San Diego Basin	14% of estuaries; minor impairment of other waterbodies; 239 acres San Diego Bay impaired supporting fish spawning/migration and rare and endangered species	Metals, pesticides, priority organics, trace elements	Estuaries affected by land disposal; other waterbodies affected by diverse mix of point and nonpoint sources	San Diego Bay, Tijuana River Estuary	Wildlife habitat; fish spawning and migration; rare and endangered species

Source: EPA analysis of 1994 California Water Quality Assessment data base; State of California data on fish and waterfowl consumption advisories. Impaired waters are defined as those that have been assessed and rated by the State of California as medium or poor water quality for at least one toxic water quality pollutant or groups of pollutants.

Some key waterbodies impaired by toxics may have changed since 1994. However, more recent data were not used because of time constraints.

Figure 5-1


LEGEND
Regional Water Quality Control Board
1 North Coast
2 San Francisco Bay
3 Central Coast
4 Los Angeles
5 Central Valley
6 Lahontan
7 Colorado River
8 Santa Ana
9 San Diego
048D-02
Del Norte
Siskiyou
Modoc
Humboldt
Trinity
Shasta
Lassen
Tehama
Plumas
Glenn
Butte
Sierra
Mendocino
Nevada
Lake
Colusa
Sutter
Yuba
Placer
Yolo
El Dorado
Sonoma
Napa
Alpine
Sacramento
Amador
Calaveras
Marin
Solano
San Joaquin
Tuolumne
Contra Costa
Mono
San Francisco
Alameda
Stanislaus
Mariposa
San Mateo
Santa Clara
Merced
Santa Cruz
Madera
Fresno
San Benito
Inyo
Tulare
Monterey
Kings
Kern
San Luis Obispo
San Bernardino
Santa Barbara
Ventura
Los Angeles
Orange
Riverside
San Diego
Imperial
1
2
3
4
5
6
7
8
9

include estuarine and freshwater fish and piscivorous animals, although the proposed criteria may not be stringent enough to provide benefits to all wildlife species currently at risk throughout the State.

- Reducing toxic contaminants to meet water quality criteria may contribute to improved conditions for the successful recovery of Federal and State threatened and endangered (T&E) species, including the Delta smelt, Desert pupfish, California brown pelican, Bald eagle, California clapper rail, California tiger salamander and western snowy plover. Statewide, T&E species may be at risk from toxics in approximately 180,000 acres of bays, harbors and estuaries, 2,000 river miles, and 230,000 acres of saline lakes.

- The greatest reductions in the likelihood of adverse toxics-related impacts on aquatic and terrestrial wildlife may accrue for the San Francisco Bay Watershed and the Central Valley. These areas have the greatest amount of toxic loadings and the greatest diversity and richness of species, populations, and communities.

- Reducing copper discharges to the Sacramento River to meet water quality criteria would result in substantial protection for 90 percent or more of the organisms and communities that are currently adversely affected.

- Reduced concentrations of both selenium and pesticides in the waters that feed the Salton Sea are expected to contribute to improved conditions for the restoration and maintenance of currently declining populations of wildlife, including threatened and endangered species. These include the California brown pelican, peregrine falcon, bald eagle, Yuma clapper rail, and desert pupfish.[4]

- All components of the ecosystem are inextricably linked. Therefore, we expect that the improved water quality and likely associated improvements in survival, growth, and reproductive capacity of aquatic and aquatic-dependant organisms resulting from reduced exposure to toxics will help to contribute to the increased stability, resilience and overall health of numerous ecosystems throughout California, and may contribute to protecting, restoring and maintaining California's rich biodiversity.

---

[4] However, current selenium criteria may not be stringent enough to adequately protect some aquatic-dependant wildlife species. The U.S. Fish and Wildlife Service is recommending a selenium criterion of 2 ug/liter to protect some of these aquatic-dependant wildlife.

Organization of the Chapter

This chapter's first section briefly describes the methodology used to characterize the ecological benefits associated with the California Toxics rule. We then describe the potential impacts of selected toxic pollutants of concern on exposed species, populations, and communities throughout the State. We next discuss the potential impact of toxics on waters of special concern, including waters that the State has designated for the support of important ecological functions, and waters that support threatened and endangered species. Finally, the chapter presents a method for examining the proposed rule's potential beneficial impacts on biological communities, presenting an illustration based on ambient water quality data from the Sacramento River. To provide additional detail on the potential ecological benefits of the proposed rule, we present case studies illustrating these benefits for two areas: the San Francisco Bay Estuary and the Salton Sea. These case studies are presented in Chapter 6.

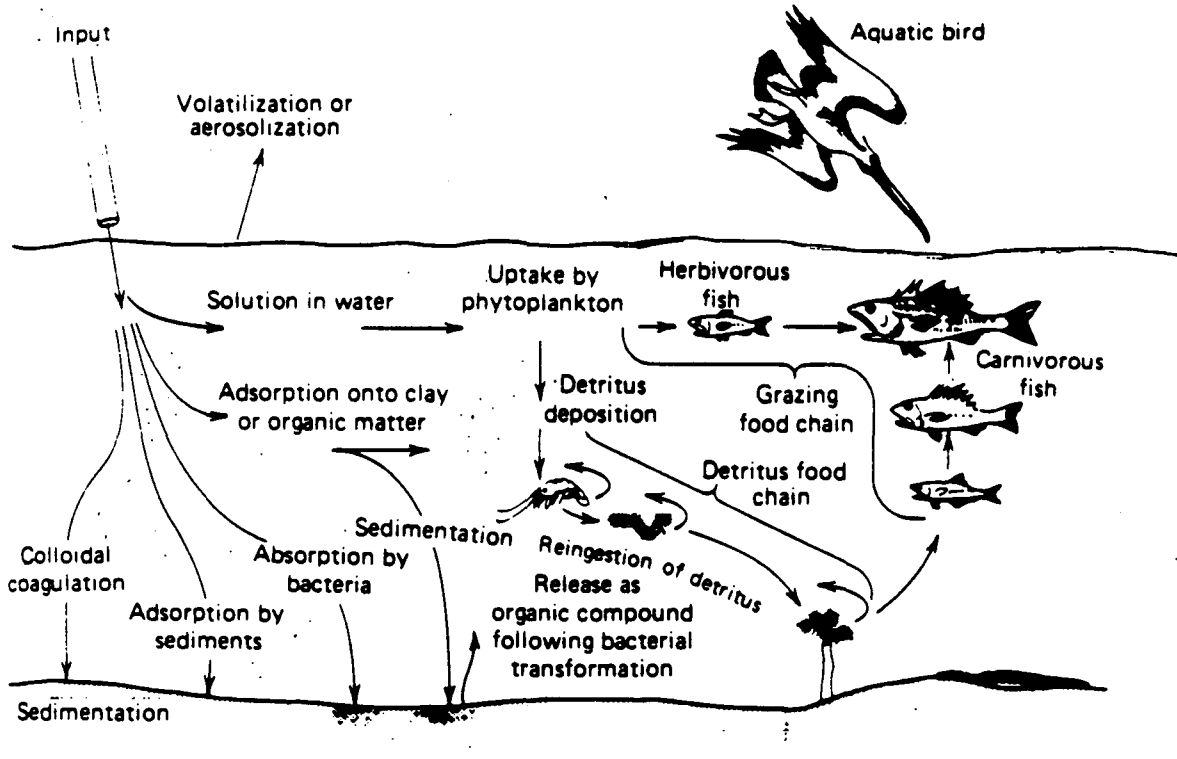
METHODOLOGY

A great proportion of the toxic compounds addressed in this rule pose morbidity and mortality risks to both aquatic and aquatic-dependant organisms at relatively low environmental concentrations. In order to more completely describe ecosystem benefits, it is necessary to consider not just toxic impacts to individual organisms, but their adverse effect on the structure and function of all components of the ecosystem. This includes population and community effects, and the complex food and energy relationships that inextricably link them all. It is also important to consider the cumulative impact of various toxics on aquatic ecosystems, and the influence of other types of stressors (e.g., habitat destruction) on the function and structure of these ecosystems.

As shown in Figure 5-2, discharges of pollutants can affect individuals, populations and communities either directly or indirectly. Toxic discharges can impair not only individual health, behavior and survival, but they can also disrupt the vital interactions and flow of energy between individuals and the other components of the food web, potentially leading to an adverse change in population and community structure and function. Further, in the same way that energy flows from primary producers (e.g., phytoplankton) to primary consumers (e.g., zooplankton and mussels), secondary consumers (e.g., fish larvae and invertebrates), tertiary consumers (e.g., fish and crabs) and to higher trophic level consumers (e.g., carnivorous fish, aquatic birds and seals), certain toxic contaminants can also be transferred and biomagnify to toxic levels as they move through and up the foodweb. Consequently, pollutants that enter rivers, lakes, estuaries and other waterbodies can bioaccumulate to very high levels in biotic tissues and can adversely impair organisms and animals that consume them, even though the pollutants occur in relatively low and non-toxic concentrations in water.

Figure 5-2

Simplified Diagram of the Flow of Contaminants Through Aquatic Food Web



Source: Westman, 1985

To capture all the ecosystem benefits associated with reduced toxic discharges to California waters, we would have to evaluate all of these interactive processes (including those associated with non-chemical stressors), in addition to individual organism effects. Appendix E describes the fundamental concepts in greater detail and provides a brief summary of the steps involved in a complete ecological risk assessment.

Because state-wide data on ecosystem impacts that can be solely attributed to toxics are limited, it was not possible to perform a comprehensive ecological risk assessment for ecosystems throughout the State. Further, a number of factors precluded us from performing numerous site or region-specific evaluations of the ecological risks posed by each constituent at each water resource covered by the CTR. These factors include the number and complexity of toxics being discharged to California waters, the variety of exposure pathways to aquatic and terrestrial wildlife and limitations in assessing strict causal linkages between toxics exposure and impacts. We therefore evaluated the range of qualitative and quantitative indicators and other relative measures of ecosystem benefits that are likely to accrue from reducing toxic contamination to surface waters and sediments to meet CTR water quality criteria.

We primarily utilize data on selected constituent-specific adverse ecological effects at the individual, population, and community level (e.g., direct mortality, reduced breeding success, and decreased productivity) that are likely to occur in California. Where possible, we also discuss higher trophic level impacts. We discuss in somewhat greater detail the ecological benefits expected to accrue in San Francisco Bay and the Salton Sea (presented separately, in Chapter 6). In addition, we quantified the areal extent of water quality improvements that may lead to improved fish spawning and migration, State and Federal rare, threatened and/or endangered species, and terrestrial and aquatic wildlife. We also estimated the potential hazard for piscivorous wildlife consuming mercury-contaminated fish in selected areas in California based on fish tissue data from throughout the State. Finally, we present and apply one approach for assessing changes in ecological risks associated with potential reductions of copper in parts of the Sacramento River.

As described in Chapter 2, we have characterized baseline water quality conditions for fresh and estuarine waters throughout the State by evaluating the State's Water Quality Assessment (WQA) database, developed and maintained by the State Water Resources Control Boards.[5] The WQA is a compilation of data from the State's nine regional Water Quality Control Boards and is organized by region and by waterbody type. It contains a range of information on surface water pollution, including the pollutants that adversely affect water quality in bodies of water that have

[5] California Water Quality Assessment, 1994.

been evaluated, the sources of pollution, the beneficial uses that are expected to experience some degree of impairment, and an overall rating of water quality.[6] The State relies on the WQA to develop the biennial water quality report required by Section 305(b) of the Clean Water Act. The WQA was last updated in 1994. In addition, we used site-specific studies to evaluate water quality, water sediment, and biotic conditions in selected water bodies such as San Francisco Bay, the Bay Delta, Sacramento River, and the Salton Sea.

ECOLOGICAL EFFECTS OF TOXIC POLLUTANTS AND AFFECTED RESOURCES

Occurrence of Toxics-Related Impairments

Based on analyses of state WQA data and other sources, it is clear that toxic pollutants covered by the proposed rule have a significant potential to affect many of California's surface water resources.[7] Exhibit 5-1 (see above) summarizes for the nine major regions in California the areal extent of toxics impairment, the pollutants of concern, the primary pollutant sources, key waterbodies impaired, and the ecological resources potentially affected. Major impacts include the following:

- Available data suggest that over 800,000 acres of assessed bays, estuaries, lakes, and wetlands are affected by one or more toxic pollutants, as are over 3,700 miles of rivers. Most notably, over two-thirds of the assessed area of both bays and saline lakes are adversely affected by toxics.

- Inorganic pollutants such as metals and trace elements (particularly selenium) are the most significant categories of toxic pollutants affecting the water quality in assessed waters statewide. Pesticides are also associated with large areas of water quality impairment.

---

[6] Currently, not all of California waters are assessed. Approximately 90 percent of all streams and rivers, 23 percent of lakes and reservoirs, and 46 percent of wetlands in the State have not been evaluated for water quality impacts.

[7] We define "impaired" waters as those that have been assessed and are rated by the State of California as medium or poor water quality for at least one toxic water quality pollutant or group of pollutants. See chapter 2 and Appendix A for a more detailed description of California water quality.

- Trace elements (especially selenium) are responsible for water quality impairment in 52 percent of all assessed Bays, 55 percent of assessed rivers and streams assessed, and 16 percent of all assessed lakes and reservoirs. In addition, they affect water quality in all saline lakes in the State.

- Based on the areal extent of contamination and the uses of affected waterbodies, San Francisco Bay and the Central Valley appear to be the areas most influenced by toxic contamination. In addition, toxics are responsible for impaired water quality in a high percentage of river and saline lake areas in the Colorado River Basin. While these areas constitute those most extensively affected by toxics, waters in all regions show some degree of toxics impairment.

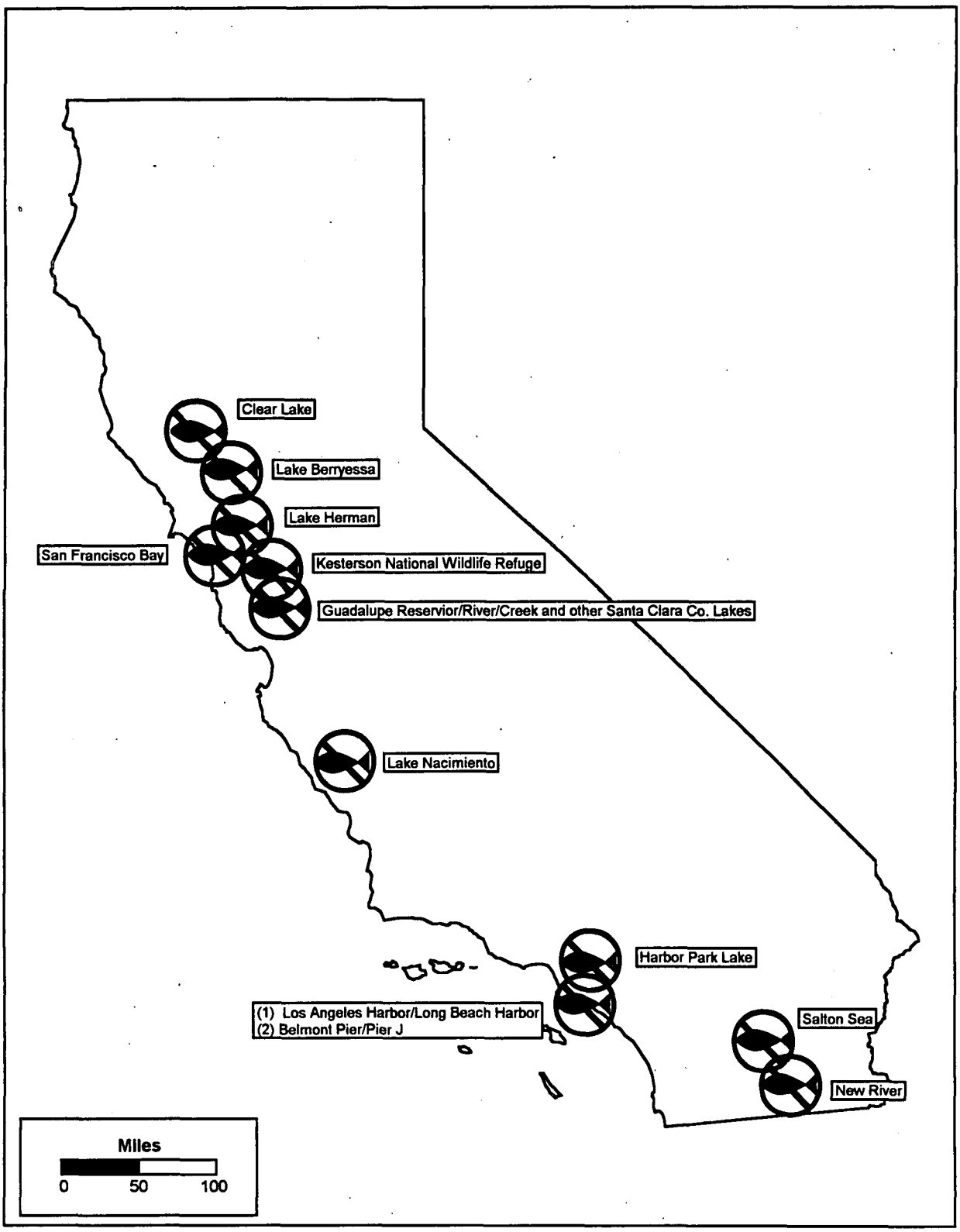
- Both point and nonpoint sources play a role in contributing to toxic pollution. Agriculture, primarily agricultural drainage, is the most frequently cited source of pollutants that impair rivers and is also frequently cited as a contributor to the impairment of lakes and reservoirs. Urban runoff and "other" nonpoint sources (e.g., deposition and spills) are most frequently cited as contributing factors to water quality problems in toxics-impaired bays. Mining is the most frequently cited point source, particularly for lakes and reservoirs, while toxics discharged by municipal wastewater treatment plants contribute to the impairment of a variety of waterbody types, particularly estuaries and wetlands.

- Currently, there are 12 fish consumption health advisories in waters covered by the CTR (nine inland waterbodies and three enclosed bays and estuaries) due to high levels of contamination in fish tissue from mercury, PCBs, chlordane, dioxin, DDT, pesticides, and selenium.[8] (Figure 5-3 shows the location of these advisories and Exhibit 3-1 in Chapter 3 identifies contaminants of concern in the 12 locations.) Some of these tissue contaminants are also hazardous to fish and piscivorous species as well.

---

[8] While the existence of fish consumption advisories for the protection of human health does not directly translate into risks to piscivorous wildlife, it does demonstrate that these pollutants accumulate to harmful levels for at least one top consumer (humans) and implies the possibility that other top consumers (piscivorous wildlife such as seals, birds, etc.) may also be at risk.

Figure 5-3
CALIFORNIA FRESHWATER AND INLAND BAYS AND ESTUARIES
FISH CONSUMPTION HEALTH ADVISORIES



- In addition there are four health warnings for consuming waterfowl taken from Grasslands area, Suisun Bay, San Pablo Bay, and San Francisco Bay based on elevated selenium levels in duck, greater and lesser scaup, and scoters. In addition to presenting a risk to human health, exposure to excessive concentrations of selenium poses a threat to the health and survival of waterfowl.

Occurrence of Toxics-Related Impairment of Ecological Beneficial Uses

Of particular importance in characterizing the potential ecological benefits of the California Toxics Rule is the extent to which California waters affected by toxics are designated to support important ecological uses. As one indicator of these impacts, Exhibit 5-2 lists all waters that (1) are identified as impaired in California's Section 303(d) report; (2) are at least partially impaired by toxics, according to the State's Water Quality Assessment (WQA) database; and (3) have associated with them one of the following current or potential beneficial uses, as indicated in the WQA:

- WILD: the support of terrestrial ecosystems, including but not limited to, the preservation and enhancement of terrestrial habitats, vegetation, wildlife, or wildlife water and food sources;

- MIGR: the support of habitats necessary for migration, spawning, or other temporary activities by aquatic organisms, such as anadromous fish; and

- RARE: the support of habitats necessary, at least in part, for the survival and successful maintenance of plant or animal species established under State or Federal law as rare, threatened, or endangered.

For each listed waterbody, the exhibit identifies the region in which it is located; the waterbody type (i.e., bay, estuary, wetland, river, or freshwater/saline lake); the priority assigned in California's Section 303(d) report for future efforts to improve water quality; the areal extent of impairment (in miles for rivers and streams and in acres for all other waterbodies); the toxic pollutants associated with the impairment; and the applicable designated use(s).[9] The designation "NA" indicates that data on beneficial uses for some waterbodies are not available.[10]

---

[9] As noted in Chapter 2, California's §303(d) report ranks impaired waterbodies for potential future action on a scale of 1 (highest) to 5 (lowest). The §303(d) priority assigned to a waterbody reflects the degree of impairment and the intrinsic value of the waterbody as a function of its current and potential beneficial uses.

[10] The exhibit includes waterbodies for which WQA data are not available on any of the three beneficial use categories.

Exhibit 5-2

ECOLOGICAL BENEFICIAL USES ASSOCIATED WITH PRIORITY WATERBODIES IMPAIRED BY TOXIC POLLUTANTS

Region	Type[1]	Waterbody Name	303(d) Priority	Area of Impairment[2]	Pollutant Types			Supports Wildlife	Supports Fish Spawn. and/or Migr.	Supports Rare or Endangered Species
1	E	ESTERO AMERICANO	2	370	Metals			X	X	X
1	E	ESTERO DE SAN ANTONIO	2	255	Metals			X	X	X
1	R	KLAMATH RIVER	1	1	Metals	Pesticides		X	X	X
1	R	MAD RIVER	2	3	Pesticides			X	X	X
1	R	SHASTA RIVER	3	2	Pesticides			X	X	
1	R	VAN DUZEN RIVER	2	2	Pesticides			X	X	X
2	B	SAN FRANCISCO BAY, CENTRAL	1	67,700	Metals	Trace Elements	Unspec. Toxics	X	X	X
2	B	SAN FRANCISCO BAY, LOWER	1	79,900	Metals	Pesticides		X	X	X
2	B	SAN FRANCISCO BAY, SOUTH	1	24,500	Metals	Pesticides	Trace Elements	X	X	X
2	B	TOMALES BAY	3	400	Metals			X	X	X
2	L	CALERO RESERVOIR	4	350	Metals	Trace Elements			X	
2	L	GUADALUPE RES	4	80	Metals	Trace Elements			X	
2	L	HERMAN LAKE	5	110	Metals			X	X	
2	R	ALAMEDA CREEK	4	27	Metals	Trace Elements		X	X	
2	R	ALAMITOS CREEK	4	14	Metals	Trace Elements		NA	NA	NA
2	R	GUADALUPE RIVER	4	30	Metals	Pesticides	Unspec. Toxics	X	X	
2	R	NAPA RIVER	3	55	Metals			X	X	X
2	R	PETALUMA RIVER	3	25	Metals			X	X	X
2	R	WALKER CREEK	4	25	Metals			X	X	X
2	W	SUISUN MARSH	1	57,000	Metals			NA	NA	NA
3	B	MONTEREY HARBOR	4	74	Metals	Unspec. Toxics				X
3	B	MORRO BAY	2	100	Metals	Unspec. Toxics		X		X
3	B	MOSS LANDING HARBOR	4	40	Pesticides			X		X
3	E	CARPINTERIA MARSH	2	80	Priority			X	X	X
3	E	ELKHORN SLOUGH	2	1,000	Pesticides	Metals		X	X	X
3	E	GOLETA SLOUGH/ESTUARY	3	200	Metals	Priority Organics		X		X
3	E	WATSONVILLE SLOUGH	4	300	Pesticides	Pesticides	Trace Elements	X	X	X
3	L	NACIMIENTO RESERVOIR	3	5,370	Metals			X	X	X
3	R	SALINAS RIVER	3	50	Pesticides			X	X	X
3	R	SAN LORENZO RIVER	3	20	Trace			X	X	X
3	W	ESPINOSA SLOUGH	4	160	Pesticides	Priority Organics		X		
3	W	MORO COJO SLOUGH	5	100	Pesticides	Trace Elements		X	X	X

Exhibit 5-2

ECOLOGICAL BENEFICIAL USES ASSOCIATED WITH PRIORITY WATERBODIES IMPAIRED BY TOXIC POLLUTANTS

Region	Type[1]	Waterbody Name	303(d) Priority	Area of Impairment[2]	Pollutant Types			Supports Wildlife	Supports Fish Spawn. and/or Migr.	Supports Rare or Endangered Species
3	W	SALINAS RIVER REFUGE LAGOON (SOUTH)	4	50	Pesticides			X	X	X
3	W	TEMBLADERO SLOUGH	3	75	Pesticides			X	X	X
4	E	MUGU LAGOON	2	1,500	Pesticides	Trace Elements		X	X	X
4	E	BALLONA WETLANDS	3	150	Metals			X	X	X
4	E	COLORADO LAGOON	3	13	Metals	Pesticides	Trace Elements	X		
4	B	LONG BEACH HARBOR (INNER)	3	840	Pesticides	Priority Organics	Metals			X
4	E	LOS ANGELES RIVER (TIDAL PRISM)	3	1,260	Metals	Priority Organics	Pesticides			X
4	R	VENTURA RIVER (LOWER)	3	6	Metals	Priority Organics		X	X	X
4	R	CALLEGUAS CREEK	4	11	Pesticides			X		X
4	L	HARBOR LAKE	4	50	Pesticides			X		X
4	R	LOS ANGELES RIVER (UPPER)	4	25	Priority	Trace Elements		X		
4	B	MARINA DEL REY HARBOR	4	354	Metals	Pesticides		X		
4	R	REVOLON SLOUGH	4	9	Pesticides			X		
4	R	SAN GABRIEL RIVER; FIRESTONE BLVD - ESTUARY	4	18	Metals	Priority Organics		X		
4	R	SAN GABRIEL RIVER (TIDAL PRISM)	4	3	Metals			X	X	X
4	B	PORT HUENEME	5	121	Metals	Priority Organics	Pesticides	X		
5	E	DELTA WATERWAYS	1	48,000	Metals	Pesticides	Unspec. Toxics	X	X	NA
5	L	BEACH LAKE	5	295	Metals	Pesticides		NA	NA	NA
5	L	BERRYESSA LAKE	3	20,700	Metals			X	X	NA
5	L	CLEAR LAKE	1	43,000	Metals			X	X	NA
5	L	DAVIS CREEK RESERVOIR	5	290	Metals			X	X	NA
5	L	KESWICK RESERVOIR	4	450	Metals			NA	NA	NA
5	L	MARSH CREEK RESERVOIR	5	375	Metals			NA	NA	NA
5	L	SHASTA LAKE	2	20	Metals			X	X	NA
5	L	WHISKEYTOWN RESERVOIR	3	3,251	Unspec.			X	X	NA
5	R	AMERICAN RIVER, LOWER	1	23	Metals	Pesticides	Unspec. Toxics	X	X	NA
5	R	FEATHER RIVER, LOWER	1	60	Metals	Pesticides	Unspec. Toxics	X	X	NA
5	R	KINGS RIVER, LOWER	4	30	Metals	Pesticides	Trace Elements	NA	NA	NA
5	R	LITTLE BACKBONE CREEK	5	1	Metals			NA	NA	NA
5	R	LITTLE GRIZZLY CREEK	5	10	Metals			NA	NA	NA
5	R	MERCED RIVER, LOWER	4	60	Pesticides	Unspec. Toxics		X	X	NA
5	R	MOKELUMNE RIVER, LOWER	4	28	Metals			X	X	NA

Exhibit 5-2

ECOLOGICAL BENEFICIAL USES ASSOCIATED WITH PRIORITY WATERBODIES IMPAIRED BY TOXIC POLLUTANTS

Region	Type[1]	Waterbody Name	303(d) Priority	Area of Impairment[2]	Pollutant Types			Supports Wildlife	Supports Fish Spawn. and/or Migr.	Supports Rare or Endangered Species
5	R	MUD SLOUGH	4	16	Pesticides	Unspec. Toxics	Trace Elements	NA	NA	NA
5	R	SACRAMENTO RIVER, SHASTA DAM TO RED BLUFF	1	50	Metals	Unspec. Toxics		X	X	NA
5	R	SACRAMENTO RIVER, RED BLUFF TO DELTA	1	185	Metals	Unspec. Toxics	Pesticides	X	X	NA
5	R	SACRAMENTO SLOUGH	5	1	Metals	Unspec. Toxics		NA	NA	NA
5	R	SALT SLOUGH	4	15	Pesticides	Trace Elements	Unspec. Toxics	NA	NA	NA
5	R	STANISLAUS RIVER, LOWER	3	48	Pesticides	Unspec. Toxics		X	X	NA
5	R	TUOLUMNE RIVER, LOWER	4	32	Pesticides	Unspec. Toxics		X	X	NA
5	W	GRASSLANDS MARSHES	2	8,224	Trace			NA	NA	NA
5	W	MORMON CHANNEL	5	1	Pesticides	Metals		NA	NA	NA
5	W	MORMON SLOUGH	5	1	Pesticides	Metals		NA	NA	NA
6	L	EAGLE LAKE (2)	2	25,000	Metals			X	X	X
6	L	FALLEN LEAF LAKE	3	1,410	Trace			X	X	
6	L	LAKE TAHOE	1	160	Metals	Pesticides		X	X	
6	L	TOPAZ LAKE	4	2,300	Trace			X	X	
6	R	BRYANT CREEK	5	10	Metals	Trace Elements		X		
6	R	CARSON RIVER, E FK	3	46	Trace	Metals		X	X	X
6	R	CARSON RIVER, W FK	4	6	Trace			X	X	X
6	R	EAST WALKER RIVER	3	8	Metals	Priority Organics		X	X	X
6	R	OWENS RIVER	2	120	Trace			X	X	
6	R	SUSAN RIVER	4	7	Metals	Trace Elements		X	X	
6	R	TRUCKEE RIVER	2	106	Trace	Priority Organics	Metals	X	X	X
6	R	WEST WALKER RIVER	3	1	Trace	Metals		X	X	
6	S	ALKALI LAKE, LOWER	3	10,855	Trace			X	X	X
6	S	HONEY LAKE	2	55,327	Trace			X		
7	R	ALAMO RIVER	4	52	Pesticides	Trace Elements		X	NA	X
7	R	COACHELLA VALLEY STORM CHANNEL	5	20	Pesticides			X	NA	X
7	R	IMPERIAL VALLEY DRAINS	5	1,305	Pesticides	Trace Elements		X	NA	X
7	R	NEW RIVER (R7)	5	60	Trace	Pesticides		X	NA	X
7	R	PALO VERDE OUTFALL DRAIN	5	16	Pesticides			X	NA	X
7	S	SALTON SEA	1	220,000	Trace			X	NA	X
8	B	UPPER NEWPORT BAY ECOLOGICAL RESERVE	2	1,500	Pesticides	Trace Elements		X	X	X
8	B	ANAHEIM BAY	3	180	Pesticides	Metals		X	X	X

Exhibit 5-2

ECOLOGICAL BENEFICIAL USES ASSOCIATED WITH PRIORITY WATERBODIES IMPAIRED BY TOXIC POLLUTANTS

Region	Type[1]	Waterbody Name	303(d) Priority	Area of Impairment[2]	Pollutant Types			Supports Wildlife	Supports Fish Spawn. and/or Migr.	Supports Rare or Endangered Species
8	L	BIG BEAR LAKE	3	2,970	Metals			X		X
8	B	NEWPORT BAY, LOWER	3	700	Pesticides	Metals	Trace Elements	X	X	X
8	L	LAKE ELSINORE	4	2,600	Unspec.			X		
8	R	SANTA ANA RIVER, REACHES 3 AND 4	4	30	Metals	Unspec. Toxics		X		X
9	B	CENTRAL MISSION BAY	3	1	Metals	Pesticides		X	X	X
9	B	OCEANSIDE HARBOR	4	1	Metals	Pesticides	Trace Elements	X	X	X
9	B	SAN DIEGO BAY, NORTH	1	239	Metals	Priority Organics	Pesticides	X	X	X
9	B	SAN DIEGO BAY, SOUTH	1	4	Metals	Priority Organics		X	X	X
9	E	TIJUANA RIVER ESTUARY	2	1	Pesticides	Metals		X	X	X
9	R	ARROYO TRABUCO	5	1	Metals			X		X
9	R	TIJUANA RIVER	5	5	Pesticides	Trace Elements	Metals	X		X

[1] Waterbody Types: B = Enclosed Bay or Harbor, E = Estuary, L = Lake or Reservoir, R = River or Stream, W = Wetland

[2] Enclosed Bays, Estuaries, Lakes and Reservoirs, and Wetlands are measured in acres. Rivers and Streams are measured in miles.

Sources: The California 303(d) report provided the priority rankings of waterbodies. California's Water Quality Assessment database provided the information on waterbodies affected by toxic pollution and the area of impairment. Regional basin reports identified the ecological beneficial uses supported by the impaired waterbodies.

Exhibit 5-3 summarizes the data by region, and Exhibit 5-4 summarizes the data for the entire State. These exhibits indicate the areal extent of waters that are impaired by toxics and are designated for support of wildlife habitat, fish spawning and migration, and rare or endangered species. As the exhibit shows, toxic pollutants are of concern in a large number of waters designated for the support of terrestrial and aquatic wildlife. In addition, water quality in 175,000 acres of bays/harbors, 52,000 acres of estuaries, 102,000 acres of lakes, 1,000 miles of rivers and streams, and 11,000 acres of saline lakes that support fish spawning and/or migration is toxics-impaired. Toxics contribute to the impairment of approximately 176,000 acres of bays or harbors, 2,000 river miles, and 230,000 acres of saline lakes designated for the support of rare, threatened, or endangered species.

Based on this statewide information, it is clear that toxic contaminants addressed by the rule are ubiquitous throughout the state, and that aquatic and terrestrial life is exposed to a range of toxic pollutants that may adversely affect their health and survival.

In interpreting the figures presented in these exhibits, it is important to note that some regions do not report all three categories of use in their water quality assessments. This is the case, for example, with Region 5, where available WQA data do not include an assessment of whether specific waters support rare, threatened, or endangered species. As a result, the analysis likely understates the extent to which toxics-impaired waters support habitats important for the survival of these species.

Exposure Pathways

Pollutants entering California waters may ultimately end up in aquatic and aquatic-dependant animals and plants through either direct or indirect pathways of exposure. Direct pathways of exposure occur when biota come in direct contact, either singularly or in combination, with toxics in the water column, sediments, or diet. For example, benthic filter feeds (e.g., oysters, clams, various crustaceans) can ingest pollutants when they pump contaminated water over their gills. Snails and worms can ingest pollutants that have adhered to sediment particles as they graze on organic matter in sediments.[11] Indirect pathways of exposure occur when ecological resources (e.g., spawning beds, prey sources) have been reduced or otherwise altered by toxics. Toxics may also bioaccumulate in organisms, making them available to terrestrial predators (e.g., fish-eating wildlife) dependant on the aquatic food web of the contaminated system. Predators such as seals, fish, ducks, and waterbirds that eat these organisms are then exposed to the pollutants in their prey tissue. The extent to which organisms are adversely affected depends on the pathway and duration of exposure as well as the concentration and type of toxics present in the pathway.

[11] U.S. EPA, 1992.

Exhibit 5-3

BENEFICIAL USES OF PRIORITY AQUATIC RESOURCES THAT ARE IMPAIRED, AT LEAST IN PART, BY TOXIC POLLUTANTS

Supports Fish Spawning and/or Migration			Supports Wildlife			Supports Rare or Endangered Species		
Region	Type*	Area of Impairment	Region	Type*	Area of Impairment	Region	Type*	Area of Impairment
1	E	625	1	E	625	1	E	625
1	R	8	1	R	8	1	R	6
2	B	172,500	2	B	172,500	2	B	172,500
2	L	540	2	L	110	2	R	105
2	R	162	2	R	162	3	B	214
3	E	1,380	3	B	140	3	E	1,580
3	L	5,370	3	E	1,580	3	L	5,370
3	R	70	3	L	5,370	3	R	70
3	W	225	3	R	70	3	W	225
4	E	1,650	3	W	385	4	B	840
4	R	9	4	B	475	4	E	2,910
5	E	48,000	4	E	1,663	4	L	50
5	L	67,261	4	L	50	4	R	20
5	R	486	4	R	72	6	L	25,000
6	L	28,870	5	E	48,000	6	R	166
6	R	294	5	L	67,261	6	S	10,855
6	S	10,855	5	R	486	7	R	1,453
8	B	2,380	6	L	28,870	7	S	220,000
9	B	245	6	R	304	8	B	2,380
9	E	1	6	S	66,182	8	L	2,970
			7	R	1,453	8	R	30
			7	S	220,000	9	B	245
			8	B	2,380	9	E	1
			8	L	5,570	9	R	6
			8	R	30			
			9	B	245	5	N/A	N/A
			9	E	1			
			9	R	6			

*B = Bays/Harbors E = Estuaries L = Lakes R = Rivers & Streams S = Saline Lakes W = Wetlands
Rivers & streams are measured in miles, all others in acres.

Exhibit 5-4

ECOLOGICAL BENEFICIAL USES OF PRIORITY AQUATIC RESOURCES THAT ARE IMPAIRED, AT LEAST IN PART, BY TOXIC POLLUTANTS

Ecological Beneficial Use of Impaired Area	Bays/Harbors (Acres)	Estuaries (Acres)	Lakes (Acres)	Rivers and Streams (Miles)	Saline Lakes (Acres)	Wetlands (Acres)
Supports rare or endangered species	San Francisco Bay: 172,500 Other Inland Bays: 3,679	5,116	33,390	1,856	230,855	225
Supports wildlife	San Francisco Bay: 172,500 Other Inland Bays: 3,240	51,869	107,231	2,591	286,182	385
Supports fish spawning and/or migration	San Francisco Bay: 172,500 Other Inland Bays: 2,625	51,656	102,041	1,029	10,855	225

Source: WQA, 1994.

Selected Pollutants of Concern and Their Ecological Effects

The California Toxics Rule proposes freshwater and saltwater water quality criteria for 120 priority pollutants, including metals, pesticides, other organics, and trace elements (see Attachment 1 at the end of Chapter 1 of this report for a complete list of CTR constituents and their proposed numeric criteria).[12] As mentioned earlier, because of time and data constraints, we were not able to perform site-specific, regional, or state-wide quantitative ecological risk analyses for each of the 120 priority pollutants covered by the CTR. Instead, the following discussion presents an overview of information on a subset of pollutants that may pose particularly significant risks to organisms throughout California's aquatic ecosystems and provides more detailed information on the ecological effects of a few selected pollutants.

Biological organisms are effective receptors for toxics in aquatic systems through the uptake, accumulation, and eventual biological disposition of contaminants. Uptake of toxics results from various exposure pathways via contaminated diet, water, and/or sediment. Consequently, biota exposed to contaminants found in California's aquatic ecosystems can experience adverse acute and/or chronic effects at the sub-cellular, cellular, and organism level. Acute effects include any toxic effect produced within a short period of time, generally 96 hours or less. Although the effect most frequently considered is mortality, the end result of an acute impact could be any harmful biological effect.

In contrast, a chronic effect is any toxic effect on an organism that results after exposure of relatively long duration (often the majority of the organism's life span). The end results of a chronic effect can be death, although the usual effects are sub-lethal such as impaired growth, reduced reproduction, developmental effects, etc. Exhibit 5-5 summarizes the major categories of adverse biotic effects that individual organisms will experience when exposed to sufficiently high levels of selected contaminants. The 14 chemicals shown here represent contaminants that are highly toxic to aquatic and aquatic-dependant organisms at relatively low levels, are highly persistent and/or bioaccumulative, have been detected or have been predicted to occur at sufficient levels to cause toxic effects in California waters, sediments and/or biota, and generally have been identified by Federal, State and local sources as being of concern in waters throughout the State.

---

[12] There are several specific constituents for certain waterbodies in California that are not included in the proposed rulemaking because EPA/State promulgated criteria for these pollutants in prior rulemakings. The Preamble provides a summary of these constituents by waterbody.

Exhibit 5-5

TOXICS OF CONCERN IN CALIFORNIA AND THEIR ADVERSE ECOLOGICAL EFFECTS

Toxic of Concern	Selected Documentation in California Waters, Sediments and/or Biota	Potential Adverse Effects to Individual Organisms
Arsenic	Endangered species, mussels, fish, sediments, water	Reduced growth and survival Impaired reproduction Impaired physiology Decreased resistance to infection Mutagenic Teratogenic Carcinogenic
Cadmium	Endangered species, mussel, fish, bird, seal, waterfowl sediments, water	Reduced growth and survival Impaired reproduction Possible mutagen Teratogenic Carcinogenic
Chromium (III and VI)	Striped bass, mussel, clam, fish, sediments, water	Reduced growth and survival Impaired reproduction Mutagenic Teratogenic Carcinogenic
Copper	Endangered species, striped Bass, mussel, clam, fish, bird, seal, sediments, water	Reduced growth and survival Impaired reproduction
Lead	Endangered species, mussel, fish, bird, seal, sediments, water	Impaired metabolism
Mercury	Endangered species, striped bass, mussel, fish, bird, seal, (piscivorous wildlife) sediments, water	Reduced growth and survival Impaired reproduction Impaired development Impaired metabolism
Nickel	Striped bass, mussel, fish, bird, seal, sediments, water	Reduced growth and survival Impaired reproduction Impaired development Impaired metabolism
Selenium	Endangered species, mussel, clam, fish, bird, seal, waterfowl, (piscivorous animals) sediments, water	Reduced growth and survival Reduced reproduction Impaired development Impaired behavior Mutagenic Teratogenic Carcinogenic
Silver	Endangered species, mussel, clam, fish, striped bass, bird, sediments, water	Reduced growth and survival Reduced reproduction Carcinogenic
Zinc	Endangered species, striped bass, mussel, fish, bird, sediments, water	Reduced growth and survival Reduced reproduction Impaired behavior Impaired physiology
Dioxins	Endangered species, wildlife, fish, piscivorous animals, waterfowl	Reduced growth and survival Reduced reproduction Impaired physiology
Endosulfan and Other Estrogenic Pesticides (1)	Endangered species, fish, striped bass, birds, waterfowl, water, sediments	Reduced growth and survival Impaired physiology Teratogenic to amphibians Reduced reproduction

Exhibit 5-5

TOXICS OF CONCERN IN CALIFORNIA AND THEIR ADVERSE ECOLOGICAL EFFECTS

Toxic of Concern	Selected Documentation in California Waters, Sediments and/or Biota	Potential Adverse Effects to Individual Organisms
Polycyclic Aromatic Hydrocarbons (PAHs)	Mussel, fish, sediments, water	Reduced growth and survival Impaired reproduction Compromised immunity Mutagenic Teratogenic Carcinogenic
Polychlorinated Biphenyls (PCBs)	Endangered species, starry flounder, black-crowned night heron, mussel, seal, waterfowl, striped bass, piscivorous wildlife, sediments, water	Reduced growth and survival Reduced reproduction Impaired behavior Compromised immunity Mutagenic Teratogenic Carcinogenic

(1) Estrogenic pesticides are those that are associated with the disruption of normal endocrine and reproductive functions. Estrogenic pesticides include banned pesticides like DDT and toxaphene, as well as currently-used pesticides, such as Endosulfan.

Sources: Brown, 1996; California Environmental Protection Agency, State Water Resources Control Board, 1994; Department of Fish and Game, State of California, 1991; Fry, 1996; Harvey, et al., 1992; Herbold, et al., 1992; Kopec and Harvey, 1995; Larry Walker Associates, 1992; Ohlendorf and Fleming, 1988; Pease, 1995; Schwartzback, et al., 1996; Setzler-Hamilton, et al., 1988; Smith and Flegal, 1993; Solomon et al., 1996; Thompson, 1996; U.S. EPA, 1985a; U.S. EPA, 1992; U.S. Fish and Wildlife Service, 1997; U.S.G.S., 1990; U.S.G.S., 1993

As shown, exposure to these pollutants at levels exceeding the proposed criteria will result in adverse effects that can change or alter the structural or functional ability of the organism to survive, reproduce, and/or flourish. Toxics present in California's aquatic systems can affect cellular metabolism and physiology and can reduce normal growth and development in organisms. Other adverse impacts from exposure to toxics include impaired ability for organisms to fight chronic and acute diseases, altered physiology and behavior, impaired reproductive health and behavior, and if concentrations are high enough, death. Exposure to certain toxics present in California's aquatic systems, including aromatic hydrocarbons and heavy metals, can also increase an organism's rate of genetic mutations. Increased rates of genetic mutations can reduce the fitness of individuals and populations, especially in contaminated areas providing breeding or spawning habitat, because there would be greater risk to embryonic life stages undergoing rapid development. Any one of these adverse effects can ultimately affect the survival, reproductive success, and overall health of a population which in turn may alter community structure, function, and overall integrity.

It is important to emphasize the bioconcentration, bioaccumulation, and biomagnification of toxic pollutants through the food web. Bioconcentration is the net accumulation of a substance by an aquatic organism as a result of direct uptake from water (through gill membranes or other external body surfaces). For example, phytoplankton and other plants can absorb metals from surrounding water and can often retain these metals and concentrate them to very high levels (e.g., some organisms can concentrate cadmium to levels 250,000 times its concentration in ambient water). Bioaccumulation refers to the net uptake from all environmental sources, including food and water. For instance, in the process of collecting essential nutrients, phytoplankton can accumulate certain chemicals which bioaccumulate in their tissues and become concentrated at levels that are much higher than in the surrounding water. When small fish and zooplankton consume these contaminated phytoplankton in vast quantities, chemicals accumulated by the phytoplankton may be further concentrated in their bodies. These concentrations then biomagnify -- that is they increase in concentration -- as they move through the food web. When top fish-eating predators (e.g., chinook salmon, gulls, herons, bald eagles, mink, otter, and seals) eat the contaminated fish, they may accumulate concentrations of a toxic chemical several orders of magnitude higher than concentrations originally present in ambient waters. These extremely high tissue residues of contaminants can cause adverse effects such as impaired reproduction, altered behavior, developmental deformities, or death.

Ten of the 14 constituents shown in Exhibit 5-5 are metals, which are acutely and chronically toxic at relatively low levels, are highly persistent and, in some instances, can bioconcentrate and bioaccumulate to extremely high levels. The other four contaminants shown are organics or groups of organics that are extremely toxic and can bioconcentrate and bioaccumulate readily. Because

these complex organic pollutants remain stored in fat, are difficult to excrete, and have extremely high bioaccumulation rates, they can easily move through the food web resulting in very high concentrations in and adverse impacts to higher trophic level organisms. The organics shown here -- dioxin, endosulfan, PAHs and PCBs -- are highly toxic in very small concentrations (e.g., parts per billion) and are extremely persistent. For instance, PCBs, which are more persistent than DDT, can bioaccumulate and biomagnify to levels up to one million times those in the water.

Specific Pollutant Effects

Toxic pollutants discharged into California's water resources can have a wide range of adverse impacts on organisms, ranging from subtle physiological changes to overt changes in reproductive success or survival. A pollutant's direct impact on a particular organism is a function of the organism's inherent sensitivity to the pollutant and the extent to which the organism is exposed (i.e., magnitude, duration, and frequency of exposure). It is known that the sensitivity of various aquatic species can vary widely depending on the pollutant. For instance, certain types of fish (e.g., chinook salmon, and rainbow trout) are considered to be extremely sensitive to low concentrations of silver while other fish species (e.g., bluegill) are not. Some toxics may disproportionately affect certain components of the food web at low concentrations while others can adversely affect species/genera in various levels of the food web at ambient concentrations. For example, the pesticide atrazine tends to be most toxic to phytoplankton and aquatic plants compared to other groups of organisms (fish, zooplankton, benthic invertebrates).[13] This is not surprising given that it is an herbicide and was developed for a specific mode of action (inhibition of photosynthesis). Other contaminants exhibit effects at multiple levels of the food web at relatively narrow concentration ranges.

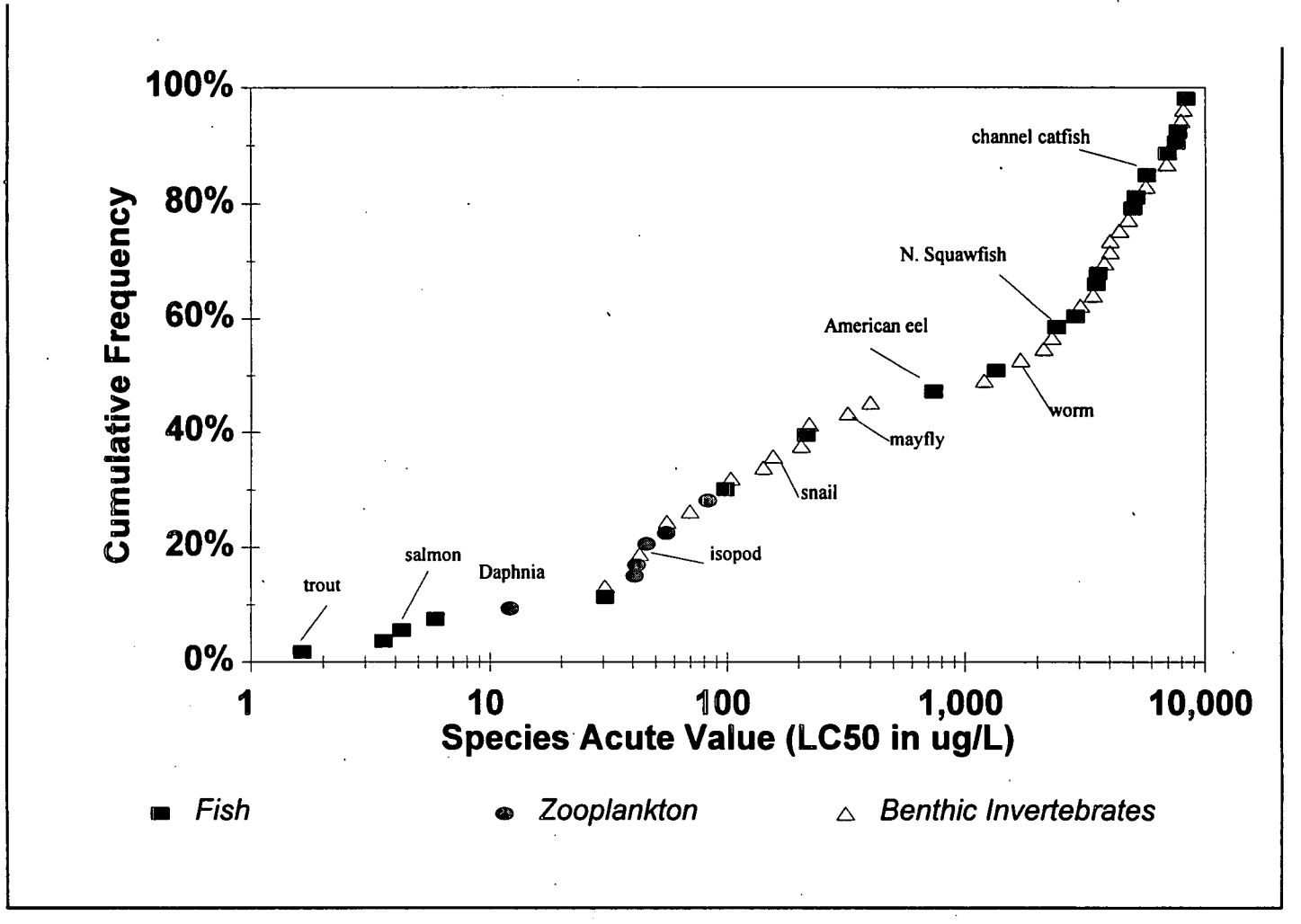
Figure 5-4 illustrates how species can vary in their sensitivity to a pollutant.[14] As shown, each data point on the horizontal axis represents a given toxicological effect concentration for an individual species (here it is the LC_{50} which is the concentration that is lethal to 50 percent of the test population). As one can see, the acute sensitivity of aquatic animals to cadmium (as measured by the acute LC_{50}) varies from 1.6 ug/l (for the brown trout) to 8,300 ug/L (for the goldfish, not labeled). The corresponding values on the vertical axis represent the cumulative rank order (expressed as a cumulative percentage) of the number of tested species that would be affected at least at a 50 percent lethal level. Thus, as the concentration increases, a greater proportion of aquatic species would be adversely affected.

---

[13] Solomon et al., 1996, Figure 17

[14] U.S. EPA, 1985a.

Figure 5-4. Acute Sensitivity Distribution of Freshwater Species Exposed to Cadmium



Source: Species Mean Acute Values from EPA Aquatic Criteria Document (U.S. EPA, 1985a)

As shown in this figure, trout are more sensitive to cadmium than are certain species of zooplankton, while other species such as mayfly and snail are more sensitive than eels or channel catfish. Similarly, the vertical axis shows that about 45 percent of the community of tested species would be adversely affected at or below the LC_{50} for American eel, while just 2 percent of the aquatic species tested would be affected at the LC_{50} corresponding to trout (or, alternatively, 98 percent of the tested species are less sensitive to cadmium compared to trout). EPA typically sets aquatic life criteria at a concentration that corresponds to the fifth percentile of species effect concentration, therefore theoretically protecting 95 percent of aquatic species. In this instance, the California cadmium criteria of 4.3 ug/liter would provide protection for most species indicated, except for some species of trout.

Exhibit 5-6 presents more detailed information on the specific adverse effects of five of the 14 pollutants across species and populations. As shown, all five of these pollutants can cause adverse impacts to all types of organisms, from reducing productivity and reproduction in zooplankton (copper), to adversely affecting reproduction in birds (estrogenic pesticides, mercury, and selenium), to impairing behavior in fish (mercury and copper). Additional information on the ecological effects of particular pollutants is provided, below.

Mercury

Mercury is among the more toxic of all heavy metals and is of great concern in both freshwater and estuarine waters in California. Mercury can bioaccumulate to concentrations nearly 100,000 times greater than concentrations in ambient waters.[15] The biological effects of mercury are extensive and widespread and adversely affect all trophic levels, from aquatic plants and invertebrates to fish, birds, and mammals. Impacts include behavioral abnormalities (inability to capture food, erratic behavior, hyperactivity, and impaired maternal-young response), impaired immune response, blindness, inhibited growth and development, decreased reproductive success and death. Mercury may cause mutagenic, teratogenic, or carcinogenic effects to aquatic organisms.

[15] U.S. EPA, 1992.

Exhibit 5-6

ECOLOGICAL EFFECTS FROM SELECTED CHEMICALS

	Organism	Population	Examples of Documented or Predicted Adverse Impacts in Selected Areas of California
Copper	Inhibited growth, enzyme activity; reduced survival, fry growth, productivity, reproduction, and blood osmoregularity; significant change in blood chemistry; decreased biomass; depressed olfactory response and feeding; asynchronous spawning; deformity; death.	Local disappearance of species; reduced species abundance (benthos).	Some waterfowl in San Francisco Bay/Delta; Aquatic species in some parts of Sacramento River. Reduced abundance, diversity and health of benthos in San Francisco Bay; impaired spawning invertebrates SF Bay;
Mercury	Abnormal mitotic activity; neurological effects; muscular atrophy; impaired growth and developmentincreased rate of respiration, reduced cardiovascular function, damage to internal organs; weight loss; spinal cord damage; impaired immune response; behavioral abnormalities; adverse reproductive effects and behaviors; loss of equilibrium; sluggishness; inability to capture food; abnormal motor coordination; hyperactivity; reduced predatory success and muscular coordination; impaired coordination, response rate and speed of response of young to maternal calls; death.	Reduced breeding success (fish and birds); population declines (fish and birds); high susceptibility to infection and infestations of parasites (birds).	Some pisciverous wildlife, including birds and mammals throughout the State; California clapper rail; populations of salmon, steel head, and other trout species in upper tributaries of Sacramento River; some threatened and endangered (T&E) species.
Selenium	reduced larvae growth; inhibited growth; pathological changes in gill tissue; degeneration and dysfunction of internal organs; swelling; chromosomal aberrations; teratogenic effects intestinal lesions; reproductive impairment; asynchronous spawning; decreased hatching rates; high rate of deformed bird embryos; reproductive failure; growth retardation; behavioral modifications; death	Reduced abundance of birds and fish; reduced reproductive success (birds); some population declines (birds).	San Francisco Bay/Delta waterfowl, bivalves and fish; impaired spawning invertebrates SF Bay; Salton Sea avian wildlife; some aquatic-dependant wildlife in Central Valley; some T&E species.

Exhibit 5-6

ECOLOGICAL EFFECTS FROM SELECTED CHEMICALS

	Organism	Population	Examples of Documented or Predicted Adverse Impacts in Selected Areas of California
Endosulfan, DDT and Other Estrogenic Pesticides	reproductive impairment; reduced fertility; eggshell thinning; decreased hatching rate; behavioral modifications; reduced breeding success; reduced growth; death	Local disappearance of avian species; some population declines.	Fish kills (bass,shad) throughout the State; some fish populations throughout the State; California Brown Pelican; some avian and fish populations in San Francisco Bay/Delta. Some T&E species.
Silver	inhibited copper synthesis; phytotoxicity; metal-induced stress in benthos; inhibited growth; increased mortality; induced selenium-vitamin E deficiency symptoms; enlarged heart; edema; CNS effects; kidney congestion; degenerative aspects in liver and kidney; decreased biomass production; coma; death.	population loss; species loss	Reduced benthos diversity and health, and decline of some fisheries in San Francisco Bay; some waterfowl in San Francisco Bay/Delta; decline of some diving birds in SFBay dependant on bivalves.

CNS = Central Nervous System; Estrogenic pesticides are those that are associated with the disruption of normal endocrine and reproductive functions. Estrogenic pesticides include banned pesticides like DDT and toxaphene, as well as currently-used pesticides, such as endosulfan.

Sources: USEPA, December 1994. Smith and Flegal 1993; EPA Ambient Water Quality Criteria for Silver, Copper, Mercury, Selenium; Luoma and Phillips, 1988; Sanders and Cibik, 1988; USFWS, May 1993; Lemley, 1992; Pease, 1995; Schwarzbach, 1996; Ohlendorf and Fleming, 1988; Larry Walker Associates, 1993; Skorupa, 1993; Fry, 1996; Thompson, 1996; Luoma and Cloern, 1982; Brown, 1996; Setzler-Hamilton, 1988; USGS 1990; USGS 1993; USEPA June 1991; USFWS, May 1992.

Mercury is a pollutant of particular concern in San Francisco Bay and in rivers and lakes throughout the state. For example, mercury is considered the primary pollutant of concern in the San Francisco Bay for one endangered species of bird (California clapper rail). Recent studies indicate that mean sediment concentrations of methyl-mercury (the more toxic form of mercury) in the bay approach calculated toxicological thresholds of about 3 ng/g.[16] Maximum methyl-mercury concentrations in sediments of the North Bay (12.5 ng/g) and the South Bay (25 ng/g) exceed the toxicological thresholds by a factor of five and 10, respectively, and approach levels believed to be associated with more severe effects. Furthermore, mercury concentrations in Clapper Rail eggs were reported to be the most contaminated in the San Francisco Bay estuary. In addition, mercury has been identified as a likely contaminant of concern for waterfowl and other avian species in the San Francisco Bay/Delta based on a hazard evaluation of reported concentrations of mercury in bird tissues or eggs (see Exhibit 5-10 and discussion in the latter part of this chapter).[17]

Mercury concentrations in California fish may also reach levels that are hazardous to piscivorous wildlife (see Exhibit 5-7). This exhibit shows a cumulative frequency distribution of total mercury concentrations found in various species of fish in California rivers and streams. These data are taken from the California Environmental Protection Agency's Toxic Substance Monitoring Database.[18] Since mercury residues in fish have been shown to correlate with fish size, the data shown here are for sizes commonly consumed by piscivorous wildlife (less than 30 cm in length). Also shown in Exhibit 5-4 are toxicological threshold concentrations determined for methyl-mercury in the diet of avian and mammalian species. Since the vast majority (i.e., >95 percent) of total mercury in fish occurs in the methylated form, comparisons between total mercury in fish to toxicological thresholds for methyl-mercury are appropriate.

The data presented in Exhibit 5-7 indicate that while the majority of mercury concentrations in fish fall below the avian and mammalian toxicological thresholds, mercury in some samples of fish may be hazardous to piscivorous wildlife. Specifically, mercury concentrations exceed the avian toxicological threshold in about six percent of the samples and the mammalian toxicological threshold in about two percent of the samples.

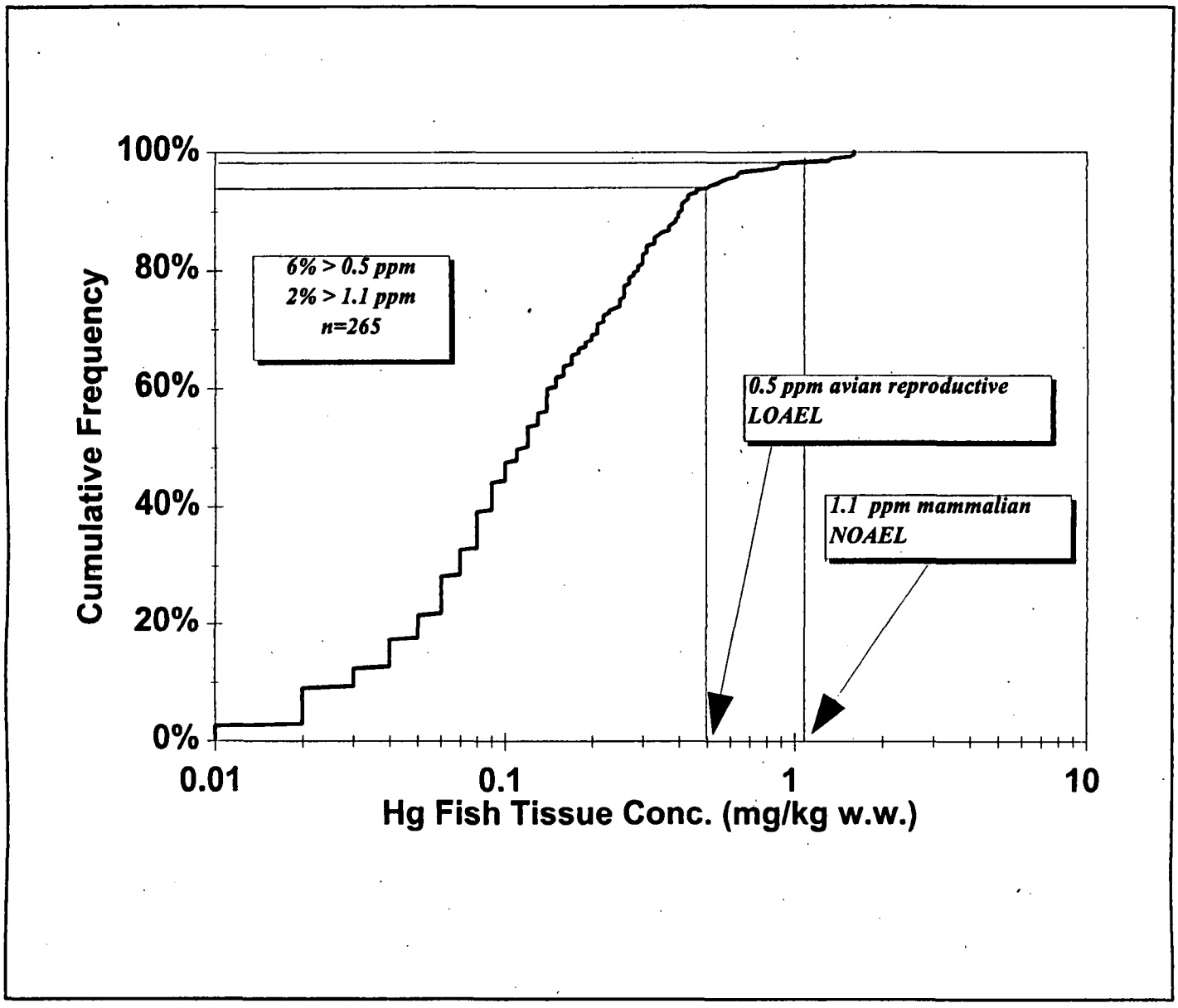
---

[16] Schwarzbach et al., USFWS, 1996.

[17] Ohlendorf and Fleming, 1988.

[18] Rasmussen, 1994.

Exhibit 5-7. Mercury Residues Reported in California Fresh Water Fish In Relation to Dietary Hazards to Wildlife



Source: Fish fillet mercury data from CA Toxics Substance Monitoring Program Database (Rasmussen 1994). Data from fish < 30 cm in length.

Avian dietary Lowest Observed Adverse Effect Level (LOAEL) from 3-generation study of mallard by Heinz (1979).

Mammalian dietary No Observed Adverse Effect Level (NOAEL) from 93-day methylmercury study of mink by Wobeser et al. (1976).

Mercury discharges to the Sacramento River can be particularly damaging. For example, mine drainage from Iron Mountain Mine contains high concentrations of mercury (along with other toxics) and has disrupted migration behavior and lowered reproduction rates in populations of salmon, steel head, and other trout species that spawn in the upper tributaries of the Sacramento River.[19] Sources of mercury include both industrial and municipal point sources as well as runoff from inactive mines.

Selenium

Selenium is much more acutely and chronically toxic at low concentrations in fresh water systems than in marine systems. Freshwater fish are particularly sensitive to ambient concentrations of selenium. Potential adverse effects include impaired reproduction (including sterilization of adults and larval mortality) and impaired physiology, deformities, and reduced growth. Current selenium criteria may not be stringent enough to adequately protect some aquatic-dependant wildlife species. Since many chemicals are not highly bioaccumulative, this practice is generally acceptable. However, in a few instances, chemicals are highly bioaccumulative and toxic to life in higher trophic levels within the surrounding ecosystem.[20]

Selenium, like other chemicals such as PCBs, mercury, and chlorinated pesticides, has also been shown to bioaccumulate and biomagnify to levels that can adversely affect wildlife at environmentally realistic concentrations. For instance, some studies have shown that, depending on the form, selenium can bioaccumulate 200,000 times by zooplankton when water concentrations of selenium are in the parts per billion.[21] Typical bioconcentration factors for selenium range between 500 and 35,000.

As a trace element, selenium is an essential part of wildlife diets. In larger quantities, however, selenium is toxic. It is important to note that there is a very narrow tolerance between beneficial and toxic doses. Generally, selenium concentrations that are ten times higher than normal

---

[19] Larry Walker Associates, March 1993.

[20] U.S. Fish and Wildlife Service recommends a criterion of 2 ug/l to fully protect aquatic and aquatic-dependant wildlife.

[21] Lemley, 1992.

background concentrations are sufficient to cause adverse biological effects.[22] Adverse effects to birds exposed to selenium through the food web include reduced survival, inhibited reproduction, reduced growth, behavioral modifications, gross deformities, immuno-suppression, and death. In addition, selenium contamination poses carcinogenic, mutagenic and teratogenic risks. Elevated concentrations of selenium may also drastically alter wildlife and fish community structure by excluding sensitive species and allowing proliferation of less desirable species.

Major human sources of selenium in California include agricultural drainage and point sources such as industrial dischargers (e.g., oil refineries). Elevated levels of selenium are estimated to impair numerous aquatic ecosystems throughout the state, although many wetlands, rivers and streams have yet to be evaluated. Based on California WQA data, we estimate that of all the waters that have been assessed, nearly 119,000 acres of bays, 3,000 acres of estuaries, 29,000 acres of lakes, 2,000 miles of rivers and streams, 286,000 acres of saline lakes and 9,000 acres of wetlands are contaminated with selenium at levels that may adversely affect both aquatic life and water-dependant wildlife. San Francisco Bay, the Central Valley, and the Colorado River Basin are areas particularly affected by selenium contamination. Selenium has been identified as a contaminant of concern for waterfowl in the San Francisco Bay/Delta based on a hazard evaluation of reported concentrations of selenium in bird tissues or eggs (see Exhibit 5-10 and discussion in the latter part of this chapter).[23] Additional research has shown that food web bioaccumulation of selenium in bivalves and fish in Suisan Bay (which is part of San Francisco Bay) is currently at levels which cause embryo malformation and reproductive failure in birds which are continuously exposed.[24]

The impact of selenium contamination drew national attention at Kesterson National Wildlife Refuge in California when selenium was identified as the cause of the disappearance of fish, the decrease in aquatic bird hatching rates, and the extremely high (64 percent) rate of deformed and dead bird embryos. Currently, the San Francisco Bay/Delta has a 5 ug/l criteria level in effect. In addition, several California Water Boards have promulgated a more stringent 2 ug/l criteria to protect

---

[22] Skorupa, 1993.

[23] Ohlendorf and Fleming, 1988.

[24] Michael Fry, "Organic Contaminants and Selenium: Implications for Waterfowl in the Bay," in 3rd Biennial State of the Estuary Conference, October 1996.

fish and wildlife from bioaccumulation of selenium. A more thorough discussion of selenium wildlife impacts is presented in the Salton Sea Case Study in Chapter 6 and in a separate document assessing the potential economic benefits of a selenium wildlife criterion in California.[25]

Copper and Silver

Copper and silver are two metals that are extremely toxic in relatively low concentrations and have been identified as contaminants of concern throughout the State. Copper can bioaccumulate in shellfish up to 30,000 times the concentration in the water while silver can bioaccumulate in shellfish/fish up to 3,000 times its ambient levels. In freshwater and saltwater, zooplankton and fish are particularly sensitive to low concentrations of copper and silver. Adverse chronic impacts to fish from these two chemicals include impaired reproductive impacts (premature hatching and reduced survival) and reduced growth. Impacts to invertebrates include impaired growth and delayed spawning. Asynchronous spawning is potentially deleterious to any organism that depends on external fertilization, which is typical of most bottom-dwelling invertebrates.[26]

Silver has been identified as a contaminant of concern throughout San Francisco Bay.[27] Metal-induced stress among benthos in the south Bay has been specifically associated with elevated silver concentrations in sediments.[28] It has been proposed that elevated silver concentrations may have limited primary productivity, reduced species diversity of benthos, and contributed to the decline of fisheries throughout the estuary.[29] Recent research in San Francisco Bay indicates that increasing concentrations of copper, silver and other metals in North Bay waters are correlated with

---

[25] See U. S. EPA, 1997 Potential Benefits of a Selenium Criterion to Protect Wildlife in California.

[26] Janet Tompson, et al., "Response of Potamocorbula amurensis to Riverine Inputs and Pollutants in Suisan Bay," in 3rd Biennial State of the Estuary Colnference, October 1996.

[27] Based on a comparison of silver concentrations measured in mussels from San Francisco Bay and mussels located in 63 other locations in North American estuaries and the northeast Pacific coastal waters, silver contamination of benthic organisms in the southern part of San Francisco Bay may be greater than or equal to that of any other estuary in North America (see Smith and flegal, 1993).

[28] Luoma and Phillips, 1988.

[29] Luoma and Cloern, 1982.

decreased condition index of bivalves, a measure of organism health.[30] Not only does this suggest that current ambient concentrations of copper and silver may be adversely affecting the growth of individual invertebrates in this estuary, but that these physiological effects might ultimately reduce the abundance or survival rate of bivalve populations. A reduction in these bivalve populations could potentially lead to changes in the availability of food for bottom-feeding fish and diving birds. In addition, the abundance of healthy clam populations is hypothesized to be crucial for controlling potentially problematic algae growth in parts of San Francisco Bay.[31]

Both copper and silver have been identified as potential contaminants of concern for waterfowl in the San Francisco Bay/Delta based on a hazard evaluation of reported concentrations of copper or silver in bird tissues or eggs[32] (see Exhibit 5-10 and discussion in the latter part of this chapter). In addition, both chronic and acute impacts associated with discharges of copper and silver from mines are a problem throughout California, particularly in the Sacramento River (see discussion in the latter part of this chapter).

Endosulfan, DDT and Other Organochlorine Pesticides: Estrogenic Pesticides

Observed levels of organochlorine pesticide contamination in California waters are associated with the disruption of normal endocrine and reproductive functions, and in some areas have caused severe impacts on entire populations of fish and birds.[33] Many of the organochlorine and organotin pesticides act in a manner that mimics the natural sex hormones of organisms. Estrogenic pesticides include banned pesticides like DDT and toxaphene, as well as currently-used pesticides, such as endosulfan.

The endocrine and reproductive disruptions associated with exposures to estrogenic pesticides in California are believed to account, in part, for observed declines in fish populations. In addition, bird species at the top of the food chain, such as the California brown pelican (a Federal

---

[30] Cynthia Brown, "Effects of Chronic Metal Contamination in Suisun Bay on Resident Populations of Bivalves," in 3rd Biennial State of the Estuary Conference, October 1996, (p. 17).

[31] Brown, 1996.

[32] Ohlendorf and Fleming, 1988.

[33] This section is based on data and information presented in Pease, 1995.

endangered species) are threatened by relatively high levels of pesticide residues in their tissues.[34] Other bird species such as gulls have been adversely affected by DDT's capacity to mimic estrogen. Populations of western gulls in southern California, for example, decreased markedly in the 1970s because of reproductive damage caused by bioaccumulate DDT in their diet.[35] It is important to note that although DDT was banned in the United States in 1962 and in Mexico in 1983, DDT continued to be released because it was present as a manufacturing impurity in dicofol, an acaricide used on cotton, one of the major crops in California. DDT and other banned chemicals are highly persistent, and consequently can continue to adversely affect organisms for decades following their ban. The entire aquatic food chain -- from aquatic plants to zooplankton, up to higher trophic levels of aquatic-based wildlife -- has been contaminated with these chemicals because of their high persistence and high bioaccumulative capacity.

One currently used pesticide, endosulfan, shares many of the hazardous characteristics of the largely banned group of organochlorine pesticides. Endosulfan tends to persist in the environment and can bioconcentrate in animal tissues. It can inhibit growth and productivity of aquatic plants and adversely impair reproduction in invertebrates. Endosulfan has been implicated in more fish kills in California than any other pesticide and is one of the most frequently detected pesticides in State monitoring programs. Because of its persistence, acute toxicity, and high bioconcentration factor, endosulfan received the highest hazard rating from the National Oceanic and Atmospheric Administration of 35 pesticides currently in use in the U.S.[36]

Pesticides such as these have been identified as likely contaminants of concern for avian species such as the snowy egret and black-crowned night heron in the San Francisco Bay/Delta based on a hazard evaluation of reported concentrations of DDE and other organochlorines in bird tissues or eggs (see Exhibit 5-10 and discussion in the latter part of this chapter).[37] In addition, field studies

---

[34] Department of Fish and Game, State of California, 1991. "Annual Report on the Status of California State Listed Threatened and Endangered Animals and Plants."

[35] Fry et al, 1987.

[36] NOAA, 1992.

[37] Ohlendorf and Fleming, 1988.

in the San Francisco Bay Delta area suggest that one of the factors contributing to the decline of striped bass populations is increased toxic pollutant burdens of chlorinated hydrocarbon residues, including DDT and other estrogen-mimicking pesticides, which have adversely affected both egg production and egg and larval survival.[38]

TOXIC POLLUTANTS AND THREATENED AND ENDANGERED SPECIES

California is one of the most biologically diverse areas in the world. Within its 160,000 square miles of land, and hundreds of thousands of acres and miles of estuaries, wetlands, rivers, streams and lakes, California harbors more unique plants and animals than any other state in the nation. The diversity of climates, landscapes, and habitats, and all the barriers to migrations such as mountains and deserts, have led over thousands of years to the evolution of a large number of isolated species and varieties of animals, many of which are found only in California.[39] For example, there are 46 species of amphibians, 96 species of reptiles, 563 species of birds, 190 species of mammals, 8,000 species of plants and 30,000 species of insects recorded in the State. The 63 types of freshwater fish are unique in that a high percentage of them are endemic to the state, that is they are found nowhere else.[40]

Unfortunately, California's biota diversity is threatened. On average, over 20 percent of the naturally occurring species of amphibians, reptiles, birds, and mammals are classified as endangered, threatened or of "special concern" by State and Federal Agencies. Sixty-three percent of California's fish species and subspecies are extinct, endangered or declining (Moyle and Williams, 1990).[41] California has more threatened and endangered species than any other state in the country. Many of these species exist in or are dependant upon aquatic resources during all or part of their lives, and consequently may be adversely affected by toxic discharges to surface waters.

---

[38] Eileen Setzler-Hamilton, et al., 1988 "Striped Bass Populations in Chesapeake and San Francisco Bays Two Environmentally Impacted Estuaries," Marine Pollution Bulletin, Volume 19, No. 9. p. 466-477.

[39] Steinhart, 1994.

[40] Moyle, 1994.

[41] Moyle, P.B. and J.E. Williams, 1990. "Biodiversity loss in the temperate zone: decline of the native fish fauna of California." Conservation Biology 4:475-484.

In an evaluation of threats to imperiled freshwater fauna in the United States (including California) experts concluded that toxic pollutants remain a serious threat for nearly 25 percent of all species evaluated.[42] Previous studies reported that the most important threats generally fall within the categories of habitat destruction and fragmentation (73% of extinctions), followed by introduced species (68%) and chemical pollution (38%). Threats to aquatic species seldom act alone; less than seven percent of federally listed fishes have a single overriding threat to their survival, whereas more than 40 percent had five or more major threats.[43]

California defines a species as endangered if it is:

- a native species or subspecies;
- a bird, mammal, fish, amphibian, reptile, mollusca, crustacean, insect or other animal, or a plant in serious danger of becoming extinct throughout all, or a significant portion of its range; and
- affected by loss of habitat, change in habitat (including degradation by pollutants) over exploitation, predation, competition, or disease.

A threatened species is one that is likely to become endangered in the foreseeable future in the absence of special protection provided by the Act.[44] Federal definitions of the terms "endangered" and "threatened" are essentially the same as the state definitions.

Many factors determine the vulnerability of a species and any single or multiple set of environmental stressors can contribute to a species' decline or extinction.[45] Some are inherent properties of the organism or species, and impart vulnerability whether the stressor is natural or

---

[42] Species evaluated included fishes, crayfishes, dragonflies and damselflies, mussels, and amphibians. See Richter, et al., 1997, in press, *Threats to Imperiled Freshwater Fauna* for more detailed discussion of these results.

[43] Wilcove, J.E., and M.J. Bean, editors, 1994: *The Big Kill*. Environmental Defense Fund, Washington, DC.

[44] California Fish and Game Code, Sec. 2067.

[45] For a more detailed discussion of factors, see Elliott Norse, Threats to Biological Diversity in the United States, September 1990.

properties of the organism or species, and impart vulnerability whether the stressor is natural or anthropogenic. Others result largely from the nature of anthropogenic stresses. Vulnerability factors include small effective population size (e.g., number of breeding males and females), species with a narrow geographic distribution, those with large area requirements, and those "amphibious" species requiring more than one type of habitat. Species requiring a particular type of habitat or food, and species intolerant of disturbance are at greater risk. Species of large organism size are vulnerable despite the advantages of large size because many natural and anthropogenic stresses (e.g., hunting) select against large organisms. Similarly, organisms with slow reproductive rates are more vulnerable to increases in mortality.

The major anthropogenic factors most affecting the survival of declining and/or threatened and endangered (T&E) species include intentional taking (e.g., hunting, trapping, fishing, and collecting), physical alteration of habitat (e.g., conversion of wetlands to agricultural or urban land), fragmentation of habitat, introduction of alien species, climate change, air pollution, and water pollution. Although physical alteration is by far the major factor contributing to the decline/extinction of a species, discharges of toxic pollutants, particularly pesticides, and other chemicals that bioaccumulate and move up the food web, can also represent a serious threat.[46]

Currently there are 151 Federally listed species in California: 122 Endangered species (68 of which are plants) and 29 Threatened species (eight of which are plants).[47] Exhibit 5-8 presents a list of these species. Pursuant to Section 7(a) of the Endangered Species Act (ESA), EPA is consulting with the U.S. Fish and Wildlife Service (FWS) and the U.S. National Marine Fisheries Service concerning this rulemaking. As part of this consultation, EPA has developed an Effect Determination Matrix to evaluate the effects of some identified issues and chemicals that FWS indicated might be of concern. These include: bioaccumulation (e.g., pesticides, mercury, and selenium); the use of dissolved metals standards; and synergistic, additive, or antagonistic effects of combinations of proposed criteria (e.g., mercury, arsenic, lead, cadmium, copper, and zinc). In addition, FWS has identified several contaminants that might be adversely affecting T&E species. These include: mercury, lead, zinc, cadmium, copper, selenium, pentachlorophenol, acrolein, chlorine, and boron.

Currently, EPA is informally consulting with FWS on these issues. Based on current information, however, it appears that threatened and endangered species throughout the State may be exposed to adverse levels of toxics, and that reducing these discharges to meet water quality criteria may be a factor contributing to the future recovery of these species. Species of particular

---

[46] Norse, 1990.

[47] Draft Endangered Species Effect Determination Matrix, U.S. EPA Region 9, prepared for California Toxics Rule Endangered Species Act Consultation, 1995.

Exhibit 5-8

CALIFORNIA TOXICS RULE ENDANGERED SPECIES ACT CONSULTATION
EFFECT DETERMINATION

STATUS	COMMON NAME	SCIENTIFIC NAME
FISH		
E	Bonytail chub	Gila elegans
E	Colorado squawfish	Ptychocheilus lucius
T	Delta smelt	Hypomesus transpacificus
E	Desert pupfish	Cyprinodon macularius
T	Lahontan cutthroat trout	Oncorhynchus clarki henshawi
T	Little Kern golden trout	Oncorhynchus mykiss whitei
E	Lost River sucker	Deltistes luxatus
E	Modoc sucker	Catostomus microps
E	Mohave tui chub	Gila bicolor mohavensis
E	Owens pupfish	Cyprinodon radiosus
E	Owens tui chub	Gila bicolor snyderi
T	Paiute cutthroat trout	Onchorynchus clarki seleniris
E	Razorback sucker	Xyrauchen texanus
PT	Sacramento splittail	Pogonichthys macrolepidotus
E	Shortnose sucker	Chasmistes brevirostris
E	Tidewater goby	Eucyclogobius newberryi
E	Unarmored threespine stickleback	Gasterosteus aculeatus williamsoni
E	Winter-run chinook salmon	Oncorhynchus tshawytscha *
AMPHIBIANS		
PE	Arroyo southwestern toad	Bufo microscaphus californicus
PE	California red-legged frog	Rana aurora draytonii
E	Desert slender salamander	Batrachoseps aridus
E	Santa Cruz long-toed salamander	Ambystoma macrodactylum croceum
REPTILES		
PE	Alameda whipsnake	Masticophis lateralis euryxanthus
E	Blunt-nosed leopard lizard	Gambelia (=Crotaphytus) silus
T	Coachella Valley fringe-toed lizard	Uma inornata
E	Desert tortoise	Gopherus (=Xerobates) agassizii
PT	Flat-tailed horned lizard	Phrynosoma mealii
T	Giant garter snake	Thamnophis gigas

T	Island night lizard	Xantusia (=Klauberina) riversiana
E	San Francisco garter snake	Thamnophis sirtalis tetrataenia
BIRDS		
T	Aleutian Canada goose	Branta canadensis leucopareia
E	American peregrine falcon	Falco peregrinus anatum
E	Bald eagle	Haliaeetus leucocephalus
E	California brown pelican	Pelecanus occidentalis californicus
E	California clapper rail	Rallus longirostris obsoletus
E	California condor	Gymnogyps californianus
E	California least tern	Sterna antillarum (=albifrons) browni
T	Coastal California gnatcatcher	Polioptila californica californica
T	Inyo brown towhee	Pipilo fuscus eremophilus
E	Least Bell's vireo	Vireo bellii pusillus
E	Light-footed clapper rail	Rallus longirostris levipe
T	Marbled murrelet	Brachyramphus marmoratus
T	Northern spotted owl	Strix occidentalis caurina
T	San Clemente sage sparrow	Amphispiza belli clementeae
E	Short-tailed albatross	Diomedea albatrus
PE	Southwestern willow flycatcher	Empidonax traillii extimus
T	Western snowy plover (coastal population)	Charadrius alexandrinus nivosus
E	Yuma clapper rail	Rallus longirostris yumanesis
MAMMALS		
E	Amargosa vole	Microtus californicus scirpensis
E	Fresno kangaroo rat	Dipodomys nitratoides exilis
E	Giant kangaroo rat	Dipodomys ingens
E	Morro Bay kangaroo rat	Dipodomys heermanni morroensis
E	Pacific little pocket mouse	Perognathus longimembris pacificus
E	Point Arena mountain beaver	Aplodontia rufa nigra
E	Salt marsh harvest mouse	Reithrodontomys raviventris
E	San Joaquin kit fox	Vulpes macrotis mutica
T	Southern sea otter	Enhydra lutris nereis
E	Stephen's kangaroo rat	Dipodomys stephensi
E	Tipton kangaroo rat	Dipodomys nitratoides nitratoides
INVERTEBRATES		
T	Bay checkerspot butterfly	Euphydryas editha bayensis
PE	Behren's silverspot butterfly	Speyeria zerene behrensii
E	California freshwater shrimp	Syncaris pacifica
PE	Callippe silverspot butterfly	Speyeria callippe callippe

CALIFORNIA TOXICS RULE ENDANGERED SPECIES ACT CONSULTATION

EFFECT DETERMINATION

E	Conservancy fairy shrimp	Branchinecta conservatio
E	Delhi Sands flower-loving fly	Rhaphiomidas terminatus abdominalis
T	Delta green ground beetle	Elaphrus viridis
E	El Segundo blue butterfly	Euphilotes (=Shijimiaeoides) battoides allyn
T	Kern primrose sphinx moth	Euproserpinus euterpe
PE	Laguna Mountains skipper	Pyrgus ruralis lagunae
E	Lange's metalmark butterfly	Apodemia mormo langei
E	Longhorn fairy shrimp	Branchinecta longiantenna
E	Lotis blue butterfly	Lycaeides argyrognomon lotis
E	Mission blue butterfly	Icaricia icarioides messionensis
E	Morro shoulderband snail	Helminthoglypta walkeriana
PE	Mount Hermon June beetle	Polyphylla barbata
E	Myrtles's silverspot butterfly	Speyeria zerene myrtleae
E	Palos Verdes blue butterfly	Glaucopsyche lygadamus palosverdesensis
PE	Quino checkerspot butterfly	Euphydryas editha quino
E	Riverside fairy shrimp	Streptocepahlus woottoni
E	San Bruno elfin butterfly	Incisalia mossii bayensis
PE	San Diego fairy shrimp	Branchinecta sandiegoensis
PE	Santa Cruz rain beetle	Pleocoma conjungens conjungens
E	Shasta crayfish	Pacifastacus fortis
E	Smith's blue butterfly	Euphilotes (=Shijimiaeoides) enoptes smithi
T	Valley elderberry longhorn beetle	Desmocerus californicus dimorphus
T	Vernal pool fairy shrimp	Branchinecta lynchi
E	Vernal pool tadpole shrimp	Lepidurus packardi
PE	Zayante band-winged grasshopper	Trimerotropis infantilis
PLANTS		
E	Amargosa nitrewort	Nitrophila mohavensis
E	Antioch Dunes evening-primrose	Oenothera deltoides ssp. howellii
T	Ash Meadows gumplant	Grindelia fraxino-pratensis
E	Baker's stickyseed	Blennosperma bakeri
E	Bakersfield cactus	Opuntia treleasei (= O. basilaris var. treleasei)
E	Beach layia	Layia carnosa
E	Ben Lomond spineflower	Chorizanthe pungens var. hartwegiana
E	Ben Lomond wallflower	Erysimum tetetifolium
PT	Big-leaved crown beard	Verbesina dissita
PE	Braunton's milk-vetch	Astragalus brauntonii
E	Burke's goldfields	Lasthenia burkei
E	Butte County meadowfoam	Limnanthes floccosa ssp. californica

CALIFORNIA TOXICS RULE ENDANGERED SPECIES ACT CONSULTATION

EFFECT DETERMINATION

E	California Orcutt grass	Orcuttia californica
E	California jewelflower	Caulanthus californicus
PE	California sea-blite	Suaeda californica
PT	Carpenteria	Carpenteria californica
PE	Chinese camp brodiaea	Brodiaea pallida
E	Chorro Creek bog thistle	Cirsium fontinale var. obispoense
E	Clover lupine	Lupinus tidestromii
PE	Coachella Valley milk-vetch	Astragalus lentiginosus var. coachellae
PT	Colusa Grass	Neostapfia colusana
PT	Conejo dudleya	Dudleya abramsii ssp. parva
PE	Contra Costa goldfields	Lasthenia conjugens
E	Contra Costa wallflower	Erysimum capitatum ssp. angustatum
E	Coyote ceanothus	Ceanothus ferrisae
E	Cushenbury buckwheat	Eriogonum ovalifolium var. vineum
E	Cushenbury milk-vetch	Astragalus albens
E	Cushenbury oxytheca	Oxytheca parishii var. goodmaniana
PE	Cuyamaca Lake downingia	Downingia con var. brevior
PT	Del Mar Mesa sand aster	Corethrogyne filaginifolia var. linifolia
PE	Del Mar manzanita	Arctostaphylos glandulosa ssp. crassifolia
PE	El Dorado bedstraw	Galium californicum ssp. sierrae
PT	Encinitis baccharis	Baccharis vanessae
E	Eureka Valley evening-primrose	Oenothera avita ssp. eurekensis
E	Eureka dune grass	Swallenia alexandrae
PE	Few flowered navarretia	Navarretia leucocehala ssp. pauciflora
PE	Fish Slough milk-vetch	Astragalus lentiginosus var. piscinensis
PT	Fleshy owl's-clover	Castilleja campestris ssp. succulenta
E	Fountain thistle	Cirsium fontinale var. fontinale
E	Gambel's watercress	Rorippa gambellii
PE	Greene's tuctoria	Tuctoria greenei
PE	Hairy Orcutt grass	Orcuttia pilosa
PE	Hartweg's golden sunburst	Pseudobahia bahiifolia
PE	Hoover's spurge	Chamaesyce hooveri
T	Hoover's wooly-star	Eriastrum hooveri
E	Howell's spineflower	Chorizanthe howellii
PE	Indian Knob mountainbalm	Ericdictyon altissumum
PE	Kelso Creek monkey flower	Mimubus shevocleii
E	Kern mallow	Eremalche kernesis
PE	Lake County stonecrop	Parvisedum leiocarpum

CALIFORNIA TOXICS RULE ENDANGERED SPECIES ACT CONSULTATION

EFFECT DETERMINATION

PE	Lane Mountain milk-vetch	Astragalus jaegerianus
E	Large-flowered fiddleneck	Amsinckia grandiflora
PT	Layne's butterweed	Senecio layneae
E	Loch Lomond coyote-thistle	Eryngium constancei
PE	Lyon's pentachaeta	Pentachaeta lyonii
PE	Many flowered navarretia	Navarretia leucocephala sp. pileantha
PT	Marcescent dudleya	Dudleya cymosa ssp. marcenscens
PT	Marin dwarf-flax	Herperolinon congestum
PE	Mariposa pussypaws	Calyptridium pulchellum
PE	Maripose lupine	Lupinus citrinum var. deflexus
E	Marsh sandwort	Arenaria paludicola
E	McDonald's rock-cress	Arabis macdonaldiana
E	Menzies' wallflower	Erysimum menziesii
PE	Metcalf Canyon jewelflower	Streptanthus albidus sp. albidus
E	Monterey gilia	Gilia tenuiflora ssp. arenaria
T	Monterey spineflower	Chorizanthe pungens var. pungens
E	Morro manzanita	Arctostaphylos morroensis
PE	Munz's onion	Allium munzii
PE	Orcutt's spineflower	Chorizanthe orcuttiana
E	Otay mesa mint	Pogogyne nudiuscula
E	Palmate-bracketed bird's-beak	Cordylanthus palmatus
T	Parish's daisy	Erigeron parishii
PT	Parish's meadowfoam	Limnathes gracilis ssp. parishii
E	Pedate checker-mallow	Sidalcea pedata
PE	Peirson's milk-vetch	Astragalus magdalenae var. peirsonii
E	Pennell's bird's-beak	Cordylanthus tenius ssp. capillaris
PE	Pine Hill ceanothus	Ceanothus roderickii
PE	Pine Hill flannelbush	Fremontodendron californicum ssp. decumbens
E	Pismo clarkia	Clarkia speciosa var. immaculata
PT	Piute Muntains navarretia	Navarretia setiloba
E	Presidio (=Raven's) manzanita	Arctostaphylos hookeri (=pungens) ssp. ravenii
E	Presidio clarkia	Clarkia franciscana
PT	Rawhide Hill onion	Allium tuolumnense
PT	Red Hills vervain	Verbena californica
E	Robust spineflower	Chorizanthe robusta
PE	Sacramento Orcutt grass	Orcuttia viscida
E	Salt marsh bird's beak	Cordylanthus maritimus ssp. maritimus
T	San Benito evening-primrose	Camissonia benitensis

CALIFORNIA TOXICS RULE ENDANGERED SPECIES ACT CONSULTATION
EFFECT DETERMINATION

E	San Bernardino Mountians bladderpod	Lesquerella kingii ssp. bernardina
PT	San Bruno manzanita	San Bruno Mountain manzanita
E	San Clemente Island Indian paintbrush	Castilleja grisea
E	San Clemente Island broom	Lotus dendroideus ssp. traskiae
E	San Clemente Island bush-mallow	Malaconthamnus clementinus
E	San Clemente Island larkspur	Delphinium variegatum ssp. kinkiense
E	San Diego button-celery	Eryngium aristulatum var. parishii
E	San Diego mesa mint	Pogogyne abramsii
PE	San Francisco lessingia	Lessingia germanorum
PE	San Jacinto Valley crownscale	Atriplex coronata var. notatior CRITICAL HABITAT ALSO
PE	San Joaquin Valley Orcutt grass	Orcuttia inaequalis
PE	San Joaquin adobe sunburst	Pseudobahia peirsonii
E	San Joaquin wooly threads	Lembertia congdonii
E	San Mateo thornmint	Acanthomintha duttonii =A. obovata ssp. d.)
PE	San Mateo woolly sunflower	Eriophyllum latilobum
E	Santa Ana River wooly-star	Eriastrum densifolium ssp. sanctorum
E	Santa Barbara Island live-forever	Dudleya traskiae
PE	Santa Clara Valley dudleya	Dudleya setchellii
E	Santa Cruz cypress	Cupressus abramsiana
PT	Santa Monica Mountains dudleya	Dudleya cymosa ssp. ovatifolia
E	Sebastopol meadowfoam	Limnanthes vinculans
PT	Shiny milk-vetch	Astragalus lentiginosus var. micans
PE	Short-leaved dudleya	Dudleya blochmaniae ssp. brevifolia
PT	Slender Orcutt grass	Orcuttia tenuis
E	Slender-horned spineflower	Dodecahama (=Centrostegia) leptoceras
E	Slender-petaled mustard	Thelypodium stenopetalum
PT	Sodaville milk-vetch	Astragalus lentiginosus var. sesquimetralis
E	Solano grass	Tuctoria (=Orcuttia) mucronata
E	Sonoma spineflower	Chorizanthe valida
PT	Spreading navarretia	Navarretia follalis
T	Spring-loving centaury	Centaurium namophilum
PT	Springville clarkia	Clarkia springvellensis
PE	Stebbin's Morning-glory	Calystegia stebbinsii
PT	Thread-leaved brodiaea	Brodiaea filifolia
PE	Tiburon jewelflower	Streptanthus niger
E	Tiburon mariposa lily	Calochortus tiburonensis
E	Tiburon paintbrush	Castilleja affinis ssp. neglecta (=C. neglecta)
PE	Triple-ribbed milk-vetch	Astragalus tricarinatus

CALIFORNIA TOXICS RULE ENDANGERED SPECIES ACT CONSULTATION

EFFECT DETERMINATION

E	Truckee barberry	Berberis (=Mahonia) sonnei
PT	Verity's dudleya	Dudleya verityi
T	Water howellia	Howellia aquatilis
E	Western lily	Lilium occidentale
PE	White-rayed pentachaeta	Pentachaeta bellidiflora

Listed and Proposed Species Administered by the Fish and Wildlife Service

Endangered Species = 122 (plants = 68)
Threatened Species = 29 (plants = 8)
Total Number Listed Species = 151 (plants = 76)

Total Number of Proposed Species = 71 (plants = 56)

*Administered by the National Marine Fisheries Service

CALIFORNIA TOXICS RULE ENDANGERED SPECIES ACT CONSULTATION
EFFECT DETERMINATION

concern are higher trophic level predators at the top of the food chain. The Delta smelt, Delta pupfish, San Joaquin kit fox, California brown pelican, Bald eagle, and California clapper rail include some of the species that have been listed. Although we do not have a map to illustrate the location of endangered species at risk throughout the State, Figure 5-5 shows the location of natural areas in California where a great many T&E species are observed either permanently or seasonally.[48]

Reducing discharges of toxic pollutants to aquatic ecosystems throughout the State, particularly chemicals that are highly persistent, bioconcentrate readily, and are highly bioaccumulative, may contribute to the improved conditions for the successful recovery of many Federal and State threatened and endangered species, and may significantly contribute to increased biodiversity in many areas of the State. It is important to note, however, that some current criteria (e.g., selenium and mercury) may not be stringent enough to adequately protect some aquatic-dependant wildlife species.

ILLUSTRATIVE ECOLOGICAL RISK ANALYSIS: THE SPECIES SENSITIVITY DISTRIBUTION APPROACH

Given the complexity of ecological interactions and the range of adverse impacts of all the pollutants covered by the CTR, it was outside the scope of this report to estimate precisely the degree to which achieving the water quality criteria would improve species, populations, and communities of organisms currently affected by toxic pollution. This section discusses one approach, which relies on comparing pollutant exposure information to species sensitivity distributions, for characterizing the link between reduced pollutant concentrations and the likelihood of reduced harmful exposures.

Recently, various aquatic ecological risk assessments have relied upon comparisons of exposure data to the entire distribution of species sensitivity (e.g., Figure 5-4) for characterizing ecological risk.[49] Such approaches offer advantages because they can help describe the likelihood (probability) that certain types of impacts would occur and some indication of the severity of direct

[48] Source: California Dept. Fish and Game, Natural Heritage Division, 1995. Significant natural areas are identified using biological criteria only, and may occur on public or private land. They include: areas supporting extremely rare species or natural communities; areas supporting associations or concentrations of rare species or communities; areas exhibiting representative examples of common or rare communities; and areas of high species-richness or habitat-richness.

[49] USEPA, April 1995; Solomon et al., 1996.

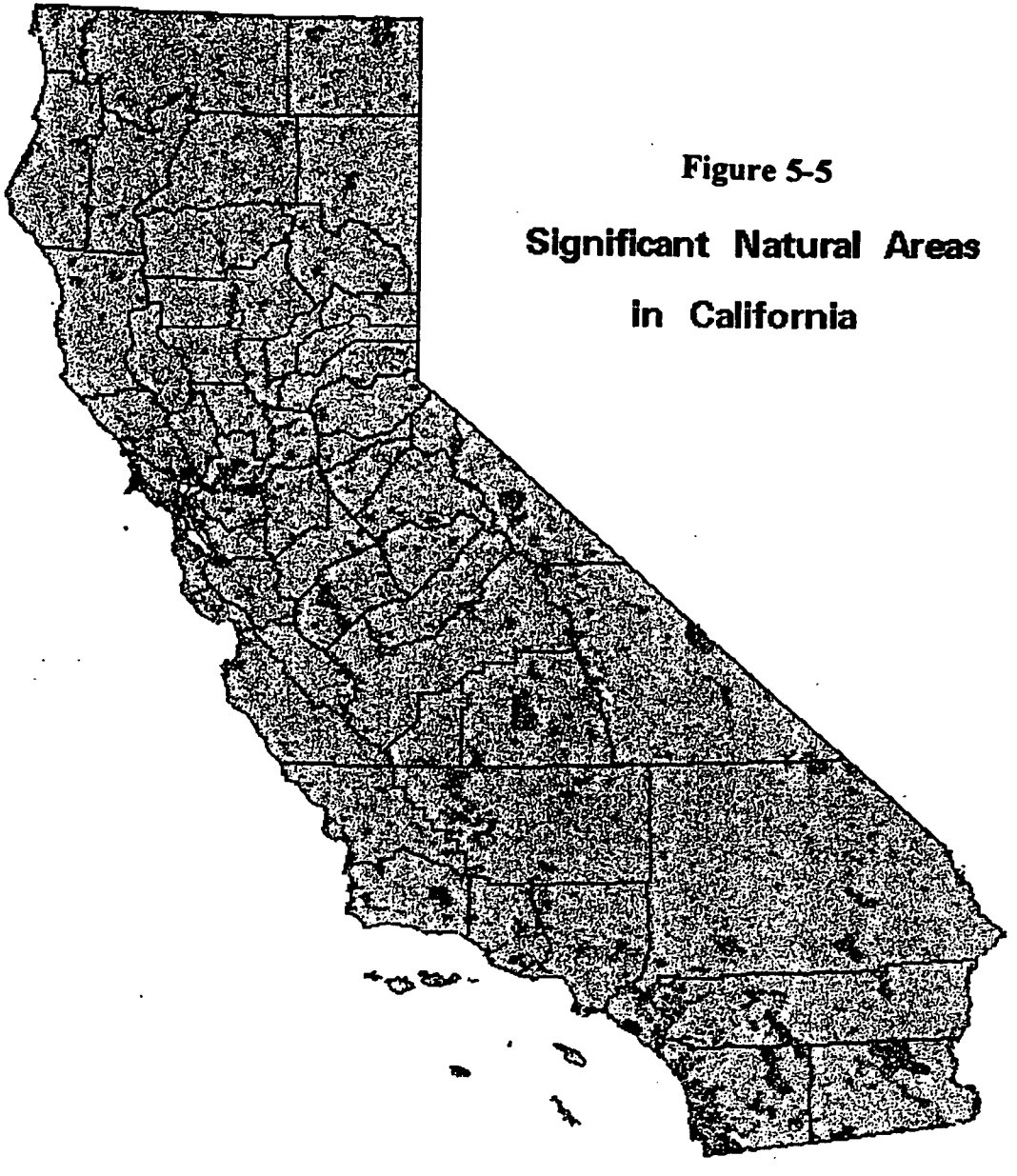


Figure 5-5

Significant Natural Areas in California

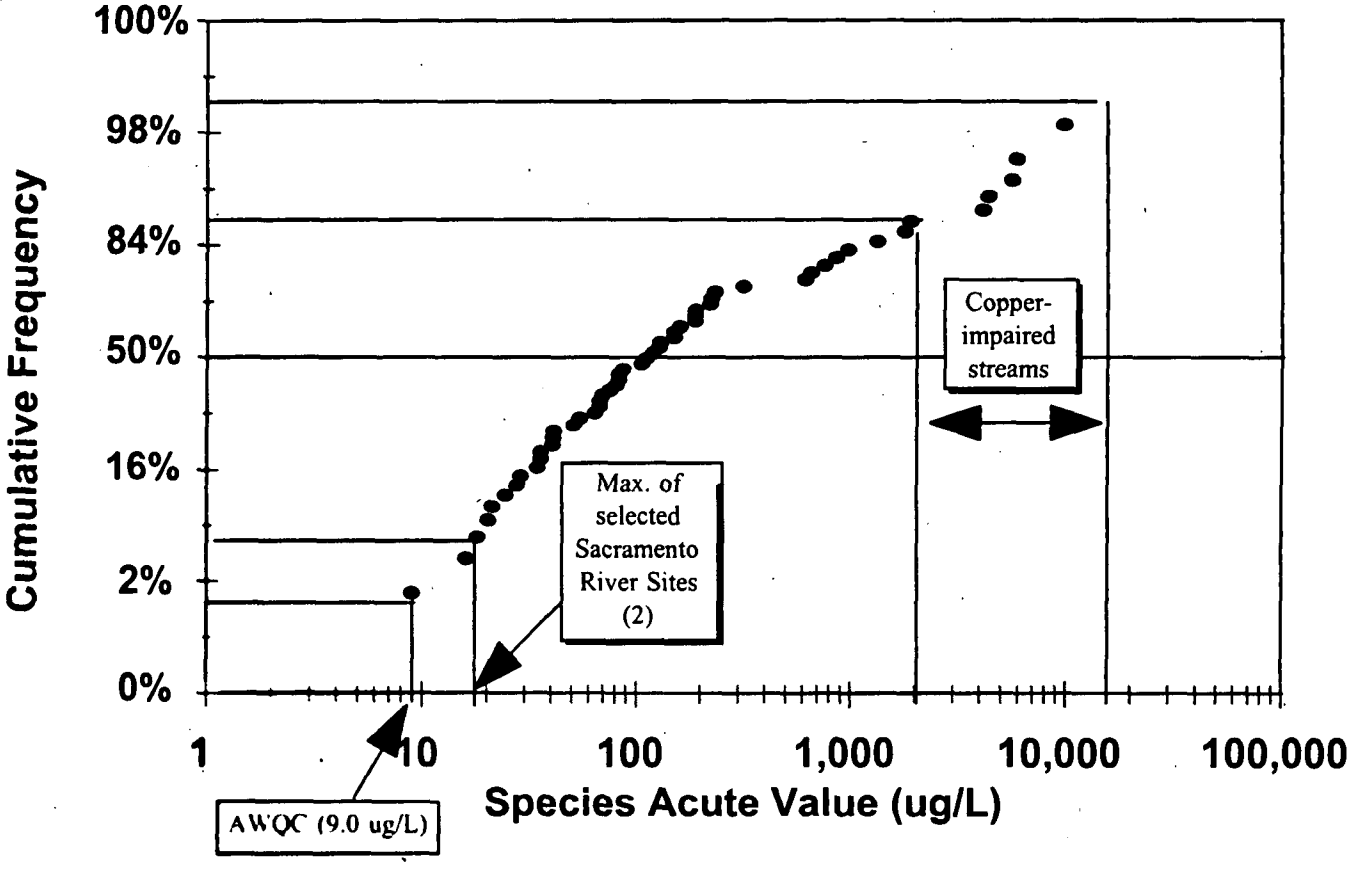
impacts based on the proportion of species likely to be affected at a given exposure concentration. As shown in Figure 5-4, different species of aquatic organisms differ widely in their sensitivity to a given pollutant (in this case, acute exposures to cadmium). Such species sensitivity distributions form the basis of EPA water quality criteria. To develop the distributions, the sensitivities of aquatic species to a contaminant are ranked in ascending order according to a common metric (in this case, the acute LC_{50}). Next, the cumulative frequency of each observation is determined based on its rank order and the total number of observations. The cumulative frequency or probability for each species sensitivity is then converted into a z-score assigned from the standard normal distribution. The z-scores (standard normal deviates) and corresponding contaminant concentrations (log scale) are regressed to derive the cumulative species sensitivity distribution. Interested readers are referred to the U.S. EPA, April 1995 and Solomon, et al., 1996 for a comprehensive discussion of the analytical process and assumptions underlying this methodology.

With some modification, species sensitivity distributions can be applied to analyze the potential benefits of the California Toxics Rule. The broad scope of the rule — both with respect to the pollutants addressed and the ecological resources affected — makes a comprehensive application of this approach impractical. For illustrative purposes, however, we apply the approach using data on copper concentrations in the Sacramento River and several of its acid mine impaired tributaries (Figure 5-6). Shown in Figure 5-6 is the cumulative distribution of acute sensitivity of aquatic species to copper. The observed acute sensitivity range for copper is from 9 ug/L for one species of the zooplankton, Daphnia, to 10,240 ug/L for one species of stonefly. As shown, the range of concentrations reported for several sites severely affected by copper-contaminated acid mine drainage (2,000 ug/L to 15,000 ug/L) exceeds the LC_{50} values for 90 percent or more of the tested species. For less adversely affected sites along the Sacramento River, the maximum concentration reported (18 ug/L) exceeds the LC_{50} value for about six percent of the tested species. Notably, the proposed copper criterion (9 ug/L) equals or exceeds the LC_{50} value for less than two percent of the tested species. Thus, reductions in copper discharges to meet the proposed criterion would afford substantial protection (e.g., up to 90 percent or more for the affected sites) to a range of aquatic species.

POPULATION, COMMUNITY AND ECOSYSTEM IMPACTS

Ecosystems are complex and dynamic functional systems that consist of all the living biotic communities and their physical environment, made up of all living organisms, their remains, and the minerals, chemical and resources on which they depend for their survival and reproduction. For the most part, we have focused on describing the impacts to individuals from toxics covered by the CTR

Figure 5-6. Selected Copper Concentrations Measured in the Sacramento River Basin Site Compared to Acute Sensitivity Distribution of Aquatic Species



Notes:

(1) Concentration ranges from 2,000 to 15,000 ug/l measured at Spring Creek, Town Cr., W. Squaw Cr., Clear Lk., & Spring Cr. Dam (as cited by Larry Walker Associates, 1992).

(2) Concentrations up to 18 ug/L measured in selected sites of Sacramento River, including Shasta & Keswick Dam, Colusa, Freeport & Hood sites (as cited by Larry Walker Associates, 1992).

Each data point denotes a Species Mean Acute Value (i.e., conc. killing 50% of individuals) for various aquatic species, Source: U.S. EPA, 1985b.

because data are most readily available for these types of effects. To describe all of the potential ecological benefits associated with toxics-reductions to California waters, however, we need to describe impacts that might be occurring at the population and community level.[50]

The effects of toxics on ecosystem structure and function above the organism level are complex, because of the diversity of species assemblages and the variety of trophic interactions between populations in aquatic food webs. Exhibit 5-9 summarizes the measures of ecosystem integrity and "health" that can be affected by toxics, to the detriment of the individual, the population, the community, and the ecosystem. Several authors have predicted the specific adverse effects of toxic stress at the ecosystem level.[51] These impacts to the structural components of ecosystems include reduced size and life-span of organisms; shortened or altered food chains; decreased species diversity and increased dominance of selected species; reduced number of native species; changes in standing crop biomass; and changes in predator/prey relationships. Under toxic stress, sensitive individuals and species can be reduced and/or eliminated and may not return until stress is removed (and assuming a species source is available for recolonization). Surviving species may exhibit broad tolerance, rapid reproduction, or resistance to the toxicant.

Toxic effects become ecologically significant for populations when they affect the survival, productivity, or function of a significant number of individuals such that population size is reduced, population structure is altered, or total function is impaired.[52] Population size can be reduced when toxic stressors reduce mating success or egg production; reduce survival of offspring or reproductive-age adults; increase susceptibility to predation, parasitism, and disease; affect recruitment through altered immigration or emigration rates; or reduce development or maturation rates. Population structure can be altered when stressors have different effects on one age group or development stage, reduce development or maturation rates, or differentially affect one sex. The resulting changes in species/population composition and number may lead to alterations in community function, the shortening of food chains, or a reversal of normal successional trends.[53]

---

[50] A population is a group of organisms of the same species generally occupying a contiguous area and capable of interbreeding. A community is an assemblage of populations living in a prescribed area or physical habitat that have a functional and compositional unity. A community may be relatively independent or dependant on neighboring assemblages.

[51] See Odum, 1985; Rapport et al, 1985; Schindler, 1987; Schaeffer, 1988; Cairns, 1992; Rapport, 1995;

[52] Cockerham and Shane, 1994.

[53] Cairns, et al, 1992.

EXHIBIT 5-9

POTENTIAL EFFECTS OF TOXIC STRESS ON AQUATIC ECOSYSTEMS

Organism Impacts	Population Impacts	System Level Impacts: Community/Ecosystem
Disease	Intraspecific behavior: territoriality, dominance	Decomposition
Mutation	Reproduction: mortality, survivorship, fecundity	Gross/net primary production
Reproduction	Physiology	Relative energy flow to grazing and decomposer food chains
Physiology	Adaption	Recovery
Growth	Disease frequency	Resiliency/Stability
Acclimation	Population survival	Resistance
Individual behavior		Species diversity
Survival		Species abundance
		Food web diversity
		Community composition

Source: Cairns, 1982; Odum, 1985; Schindler, 1987; Schaeffer, 1988; Cockerham et al, 1994.

Adverse impacts to ecosystem function from biotic exposure to both acute and chronic toxics can include changes in important processes such as primary production, nutrient cycling, or community respiration; changes in relative energy flow to grazing and decomposer food chains; and changes in mechanisms of, and capacity for, dampening undesirable oscillations.[54] Ultimately, toxic stress has the potential for reducing the overall stability and diversity of aquatic ecosystems.[55]

It is difficult to measure comprehensively the toxic-induced ecological effects at the population and community level because of the complexity and diversity of species assemblages and their interactions in the food chain. Further, changes in ecological interactions that might be indicative of toxic stress may be difficult to identify relative to natural variability or other confounding environmental impacts (e.g., habitat loss). One such study that is illustrative of the potential impact of toxics on trophic relationships within an ecosystem, and offers some insight into the potential adverse effects of contaminants transferred through the ecosystem, is a study of phytoplankton in the Chesapeake Bay.[56] The study showed that phytoplankton assemblages exhibited rapid, large shifts in species composition and succession of dominant species in response to low-level metal contamination. This resulted in dramatically altered phytoplankton communities and affected succession of dominant species, suggesting a potential to significantly affect higher trophic levels which feed on the phytoplankton (e.g. zooplankton, fish). In addition, the arsenic-induced changes in species composition and species succession, and the associated shift in carbon transfer within the estuary, was predicted to contribute to the problem of oxygen depletion in bottom waters of the Bay. Consequently, the chronic loading of arsenic was thought to have potentially serious implications for the estuary as a whole.

Summary of California Population Effects

Few studies have evaluated or predicted the adverse effects of chronic level loadings of pollutants to the different trophic levels in California ecosystems. Because structural effects (e.g., loss of sensitive species) are easier to measure than functional endpoints (e.g., community respiration), and because functional endpoints may be somewhat less sensitive to toxic effects than structural properties in certain ecosystems with functional redundancy (where several species may perform similar functions), there are more data and research available on the adverse toxic impacts

[54] Schaeffer et al, 1988.

[55] D.J. Rapport, et al, 1985.

[56] Sanders and Cibik, 1988.

to species diversity, size distribution, and population declines.[57] The majority of toxics-associated trophic level effects that we have been able to document for California have also been at the population level, and include reduced recruitment, increase in disease, and changes in abundance. Reducing loadings of toxic contaminants to California waters to meet water quality criteria may significantly contribute to the eventual recovery of selected populations, and improve the overall health and stability of aquatic ecosystems. Some specific examples are described below.

Exhibit 5-10 presents a summary of a hazard evaluation for waterfowl and other avian species from selected pollutants found to be contaminating bird tissues or eggs in populations in San Francisco Bay and the Delta. The exhibit shows that mercury, selenium, DDE, and PCBs are occurring in concentrations in some samples that are equal to or greater than those associated with adverse effects. Wildlife species potentially affected include Greater scaup, Lesser scaup, Surf scoter, and Black-crowned night heron. Other contaminants such as silver, cadmium, copper, zinc, DDE, PCBs, and other organochlorines are occurring in elevated concentrations to warrant some concern. Species potentially affected include Greater scaup, Lesser scaup, Surf scooter, Black-crowned night heron, Caspian tern, and Forster's tern.

Raptor populations (e.g., peregrine falcons and bald eagles) in California have increased from historic lows that were caused by a variety of stresses, including DDT and other pesticides. Populations of the California brown pelican, California clapper rail, and California gull have similarly increased. Despite this recovery, however, populations of these birds generally remain below historic levels, which may be partly a result of the continuing impacts from bioaccumulate toxics.

Migratory shorebird populations are extremely vulnerable to environmental stresses, in part, because they concentrate on a relatively small number of traditional stopover sites on their long journeys to and from their northern and southern feeding grounds (Figure 5-7 illustrates the migratory routes of these shorebirds). Shorebird populations have been declining throughout California (e.g., San Francisco Bay, Monterey Bay, and Newport Bay). Destruction of habitat, combined with toxic pollutant stresses (e.g., PCBs and pesticides) and other stresses are believed to be contributing to the decline of these bird populations.

---

[57] Unfortunately, testing focused on single species cannot predict numerous effects that would be expected at the community and ecosystem level. For example, single species toxicity tests can underestimate ecological effects when pollutants bioaccumulate or when a pollutant eliminates key species or adversely affects species performing key ecosystem functions. (Cairns, et al., 1992).

Exhibit 5-10

HAZARD EVALUATION OF ENVIRONMENTAL CONTAMINANTS IN BIRD TISSUES OR EGGS FROM SAN FRANCISCO BAY DELTA*

(From Ohlendorf and Fleming, 1988)

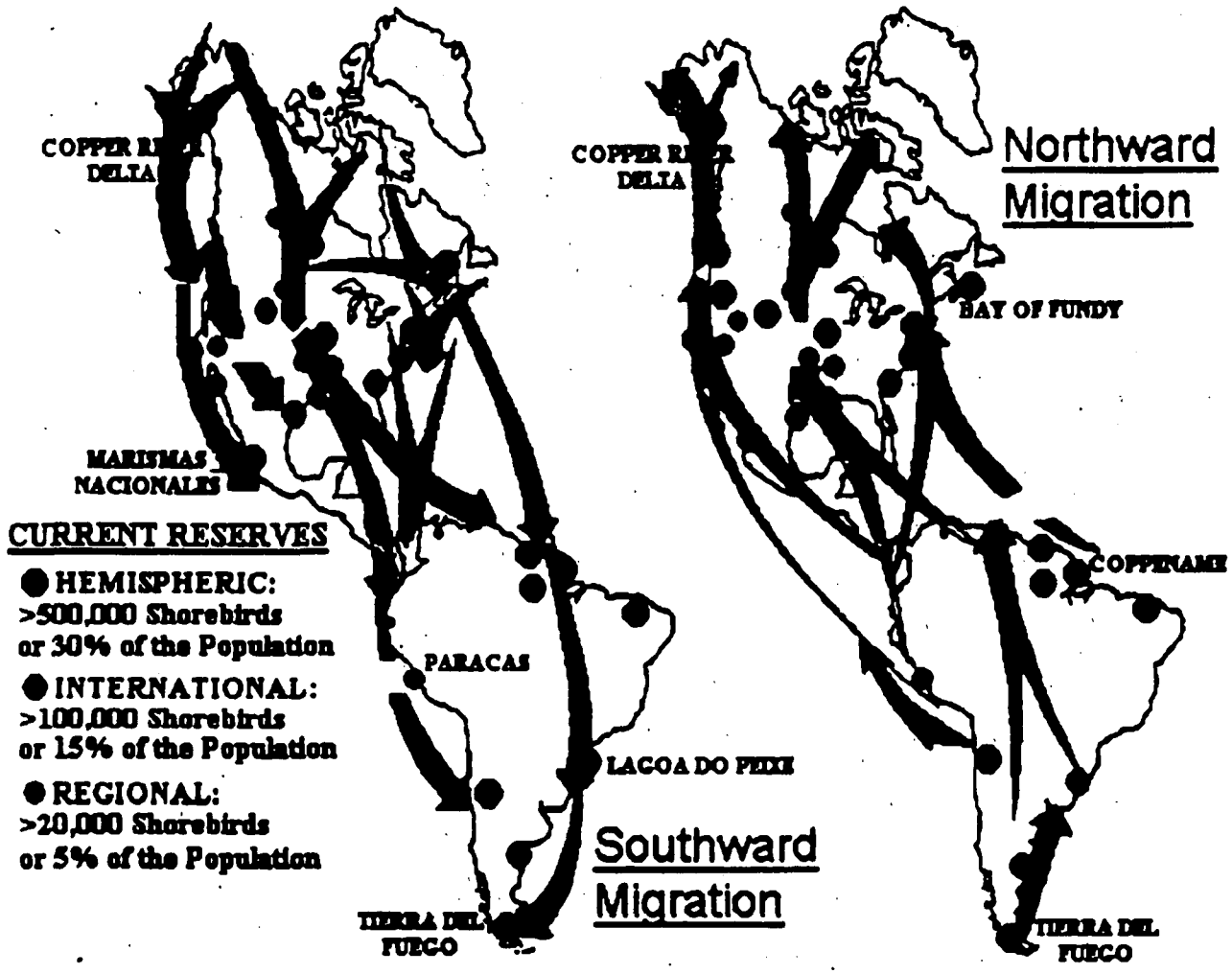
Species	Trace Elements									Organochlorines			References**
	Ag	Cd	Cr	Cu	Hg	Ni	Pb	Se	Zn	DDE	PCBs	Others	
Waterfowl													
Mallard	ND	ND	ND	ND	ND	ND	ND	-	ND	ND	ND	ND	1
Northern pintail	ND	ND	ND	ND	ND	ND	ND	ND	ND	-	-	-	2
Northern shoveler	ND	ND	ND	ND	ND	ND	ND	-	ND	ND	ND	ND	3
Canvasback	ND	ND	ND	ND	ND	ND	ND	+	ND	ND	ND	ND	3
Greater scaup	+	+	-	+	++	-	-	++	+	ND	ND	ND	1,3,4,5, 6,7,8,9
Lesser scaup	ND	ND	ND	ND	ND	ND	ND	++	ND	ND	ND	ND	1,3
Surf scoter	+	+	-	+	++	-	-	++	+	ND	ND	ND	1,3,4,5,6,7,9
Other species													
Double-crested cormorant	ND	ND	ND	ND	ND	ND	ND	?	ND	ND	ND	ND	1,10
American bittern	ND	ND	ND	ND	ND	ND	ND	-	ND	ND	ND	ND	3
Snowy egret	ND	ND	ND	ND	?	ND	ND	ND	ND	+	+	+	11,12
Black-crowned night heron	ND	ND	ND	ND	+	ND	ND	ND	ND	++	++	+	11,13,14
American coot	ND	ND	ND	ND	ND	ND	ND	-	ND	ND	ND	ND	1,3,15,16
Black-necked stilt	ND	ND	ND	ND	ND	ND	ND	-	ND	ND	ND	ND	1,15,16,17
American avocet	ND	ND	ND	ND	ND	ND	ND	-	ND	ND	ND	ND	1,15,17
Willet	ND	ND	ND	ND	ND	ND	ND	-	ND	ND	ND	ND	1
Caspian tern	ND	ND	ND	ND	?	ND	ND	ND	ND	+	+	+	11
Forster's tern	ND	ND	ND	ND	?	ND	ND	ND	ND	+	+	+	11

*Listed as follows, based upon field or laboratory determinations with these or other avian species:

"++" = reported concentrations in some samples are equal to or greater than those associated with adverse effects;
"+" = reported concentrations are elevated to warrant some concern although effect levels are not well known,
"-" = reported concentrations are not elevated in comparison with other areas or are below the known effect level;
"?" = relative status unknown (because comparative or effect levels are not known);
"ND" = no data available.

**References 1 = White *et. al.* (1987), 2 = Ohlendorf and Miller (1984), 3 = White *et. al.* (1988), 4 = Heinz (1979), 5 = Vermeer and Peakall (1979), 6 = Di Giulio and Scanlon (1984), 7 = Ohlendorf *et. al.* (1986c and in press c), 8 = Gochfeld and Burger (1987), 9 = Heinz *et. al.* (1987), 10 = King and Cromartie (1986), 11 = Ohlendorf *et. al* (in press a); 12 = Ohlendorf *et. al.* (1979), 13 = Ohlendorf *et. al.* (1978), 14 = Hoffman *et. al.* (1986), 15 = Ohlendorf *et. al.* (1987), 16 = Presser and Ohlendorf (1987), 17 = White and Cromartie (1985).

Figure 5-7
Shorebird Migration Patters of the Western Hemisphere



Colonial wading birds are in significant decrease nationwide and declines are most serious in California and Florida, where there has been almost total collapse of a wading bird population that once numbered in the hundreds of thousands.[58] In California, these include birds such as black-crowned night herons and egrets. Although habitat loss due to wetland conversion represents the key stressor, pesticide pollutants and contaminants associated with irrigation return flows (e.g., selenium, arsenic, mercury, etc.) have had significant local impacts.[59]

Waterfowl populations in California may also be at risk from selenium and pollutants that move through the food web and contaminate food sources. As described in Chapter 6, population declines of waterfowl in the Salton Sea may be caused, in part, by exposure to selenium and pesticides.[60] Migrating waterfowl populations that use California estuarine areas as staging areas along the Pacific Flyway, have also been declining.[61] Contaminants thought to be adversely affecting migratory waterfowl include cadmium, selenium, and mercury. Migratory birds wintering in the Imperial Valley, where they bioaccumulate DDT, suffer reproductive problems in their northern breeding grounds, suggesting potential population impacts.[62]

Disease is a major cause of declining populations of waterfowl wintering in the Delta, San Francisco Bay, and throughout the State.[63] The effects of disease are compounded as populations concentrate in increasingly small habitat areas. Overcrowding, poor habitat and water quality, and adverse weather may contribute to the spread of diseases such as avian cholera and botulism. For instance, the San Francisco Bay/Delta are two of the four areas in the State considered to be focal points of avian cholera. Expansion in the range of cholera outbreaks during the last 40 years is thought to be a result of interactions among the disease, habitat deterioration, and increasing pollution from chlorinated pesticides.[64]

---

[58] Ogden, 1987.

[59] Norse, 1990.

[60] Pease, 1995.

[61] U.S. EPA, 1992.

[62] Pease, 1995.

[63] U.S. EPA, 1992.

[64] McLandress, 1983.

Finally, other recent studies suggest that adverse population impacts occurring in California could be attributable, in part, to toxic pollutants. Toxic water quality is a contributing factor in the decline of winter-run chinook salmon populations that utilize the Sacramento River.[65] It has been proposed that elevated silver concentrations may have limited primary productivity, reduced species diversity of benthos, and contributed to the decline of fisheries throughout the San Francisco Bay Delta estuary. [66] Other field studies in this estuary/delta suggest that one of the factors contributing to the decline of striped bass populations is increased toxic pollutant burdens of chlorinated hydrocarbon residues, including DDT and other estrogen-mimicking pesticides, which have adversely affected both egg production and egg and larval survival.[67]

Additional research has shown that food web bioaccumulation of selenium in bivalves and fish in Suisan Bay (which is part of San Francisco Bay) is currently at levels which cause embryo malformation and reproductive failure in birds which are continuously exposed. [68] This recent data indicates an increasing reproductive risk to waterfowl populations (e.g. scaup and scoters) wintering in San Francisco Bay. Resident harbor seal populations in the Bay may also be adversely affected by PCB contamination, which has been measured in seal tissue at levels associated with immune suppression and reduced reproductive capacity.

Potential Biodiversity Effects

California's aquatic ecosystems include trophic webs of phytoplankton, invertebrates, fish, birds, mammals and other organisms that are all intricately connected to each other by the complex flow of matter and energy. Reducing toxic discharges and exposures that result in increased health and stability of individuals and species will also help to contribute to improving and maintaining the health and survival of other species, populations, and communities throughout the food web. This

---

[65] Department of Fish and Game, State of California, 1991.

[66] Luoma and Cloern, 1982.

[67] Eileen Setzler-Hamilton, et al, 1988.

[68] Michael Fry, 1996.

benefit -- improving and maintaining biodiversity[69] in the ecosystem -- is significant because the resilience and stability of most ecosystems (the rapid recovery from any kind of natural or man-made disturbance) is based, in part, on the presence of many stable and healthy species and populations.[70]

Data and time constraints have prevented us from performing an in-depth evaluation of the biodiversity benefits that might be associated with reducing toxic discharges in California to meet water quality criteria. It is possible, however, to use information derived from a national assessment of impacts affecting biodiversity to make some general conclusions about biodiversity benefits in California associated with reducing toxics to meet water quality criteria.

As described earlier, many factors determine the vulnerability of species, and any single or multiple set of environmental stressors can contribute to a species decline or extinction.[71] Some are inherent properties of the organism or species, and impart vulnerability whether the stressor be natural or anthropogenic. Others result largely from the nature of anthropogenic stresses. The major anthropogenic factors affecting the survival of declining and/or threatened and endangered (T&E) species include intentional taking (e.g., hunting, trapping, fishing, and collecting), physical alteration of habitat (e.g., conversion of wetlands to agricultural or urban land), fragmentation of habitat, introduction of alien species, climate change, air pollution, and water pollution. Although physical alteration is by far the major factor contributing to the decline/extinction of a species, discharges of toxic pollutants, particularly pesticides, and other chemicals that bioaccumulate and move up the food web, also represent a serious threat.[72]

Exhibit 5-11 presents a summary and ranking of factors affecting biological diversity in freshwater and marine systems throughout the United States. As shown, pesticides and discharges from industrial facilities (defined primarily as toxic pollutants) can represent very serious threats. In freshwater systems, pesticides and toxics from industrial sources can represent a very serious threat to insects in streams; fish, mollusca and algae/submerged aquatic vegetation (SAV) in rivers; and fish, insects and algae/SAV in lakes/wetlands. They can also pose substantial impacts to fish,

---

[69] Biodiversity refers to the variety of life forms, the ecological roles they play, and the genetic diversity they contain (see Angermeir, et al., 1994).

[70] Odum, 1993.

[71] For a more detailed discussion of factors, see Elliott Norse, *Threats to Biological Diversity in the United States*, September 1990.

[72] Norse, 1990.

EXHIBIT 5-11

Overview of Threats to Biological Diversity in the Contiguous 48 States

○ Minor impact
⊘ Substantial impact
● Very serious threat
? Lack of or conflicting information

	Intentional Taking	Incidental Taking	Physical Alteration	Pesticides	Industrial Discharges	Fertilizers/ Sewage	Solid Wastes	Air Pollutants	CO_2	UV-B	Climatic Change	Alien Species	Nuclear Wastes
FRESHWATER													
Stream													
Amphibians	○	○	●	⊘ ?	⊘	⊘	○	●	○	⊘?	●	○	○
Fishes	○	○	●	⊘	⊘	⊘	○	●	○	○	●	⊘	○
Insects	○	○	●	●	⊘	⊘	○	●	○	○	⊘	⊘	○
Producers	○	○	⊘	⊘ ?	⊘	●	○	●	○	○	⊘	○	○
River													
Birds	⊘	○	⊘	⊘	⊘	⊘	○	○	○	⊘?	⊘	○	○
Reptiles	○	○	⊘	○	○	○	⊘	○	○	○	⊘	○	○
Amphibians	○	○	⊘	⊘ ?	⊘	⊘	○	○	○	○	●	○	○
Fishes	○	○	●	⊘	●	⊘	○	○	○	○	●	○	○
Molluscs	⊘	○	●	○ ?	●	⊘	○	○	○	○	●	○	○
Insects	○	○	⊘ ?	⊘ ?	⊘	●	○	○	○	○	⊘	○	○
Emerg Plants	○	○	⊘	⊘ ?	⊘	⊘	○	○	⊘	⊘?	●	○	○
Algae/SAV	○	○	⊘	⊘ ?	●	●	○	○	○	○	⊘	○	○
Lake/Wetland													
Birds	⊘	○	⊘	⊘	⊘	○	○	⊘	○	⊘?	⊘	○	○
Amphibians	○	○	⊘ ?	⊘ ?	⊘	⊘	○	●	○	○	●	○	○
Fishes	○	○	⊘	⊘ ?	●	●	○	●	○	○	●	●	○
Molluscs	○	○	⊘ ?	⊘ ?	⊘	⊘	○	⊘	○	○	●	○	○
Insects	○	○	⊘ ?	⊘ ?	●	⊘	○	⊘	○	○	⊘	○	○
Emerg Veg	○	○	⊘	⊘ ?	⊘	○	○	○ ?	●	⊘?	⊘	○	○
Algae/SAV	○	○	⊘ ?	⊘ ?	●	●	○	⊘ ?	○	○	⊘	○	○
Cave Dwellers	⊘	○	⊘	⊘ ?	⊘	○	○	⊘ ?	○	○	⊘	○	○

Source: Norse. 1990.

EXHIBIT 5-11

Overview of Threats to Biological Diversity In The Contiguous 48 States

○ Minor impact
⊘ Substantial impact
● Very serious threat
? Lack of or conflicting information

	Intentional Taking	Incidental Taking	Physical Alteration	Pesticides	Industrial Discharges	Fertilizers/ Sewage	Solid Wastes	Air Pollutants	CO_2	UV-B	Climatic Change	Alien Species	Nuclear Wastes
MARINE													
Estu/Intr Tidal													
Birds	○	○	⊘	⊘	⊘	○	⊘	⊘	○	⊘	⊘	○	○
Fishes	⊘	○	○	○	⊘	●	○	○	○	○	⊘	○	○
Inverts	⊘	○	⊘	○	⊘	●	○	⊘	○	⊘	⊘	⊘	○
Dune Veg	○	○	●	○	○	○	○	⊘ ?	⊘	○	⊘	○	○
Mangroves	○	○	●	○	⊘	⊘	○	○	○	○	○	○	○
Seagrasses	○	○	●	○	⊘	⊘	○	⊘ ?	○	⊘ ?	○	○	○
Algae	○	○	○	○	⊘	●	○	⊘ ?	○	⊘ ?	⊘	⊘	○
Nearshore													
Mammals	○	⊘	○	⊘ ?	⊘	○	●	○	○	⊘	⊘	○	○
Birds	○	⊘	⊘	⊘ ?	○	○	●	⊘ ?	○	⊘	⊘	○	○
Reptiles	○	●	⊘	⊘ ?	○	○	●	○	○	⊘ ?	○	○	○
Fishes	⊘	⊘	○	○	⊘	⊘	⊘ ?	○	○	○	⊘	○	○
Plankton	○	○	○	○	⊘	⊘	○	○	○	●	⊘	○	○
Brith Inverts	⊘	⊘ ?	⊘	○	⊘	⊘	○	○	○	○	⊘	○	○
Seagrasses	○	○	⊘	⊘ ?	⊘	●	○	○	○	⊘	⊘	○	○
Coral Reefs	⊘	⊘	⊘	○	⊘	●	○	○	○	○	○	○	○
Offshore													
Mammals	○	●	○	○	○	○	●	○	○	○	○	○	○
Birds	○	●	○	○	○	○	●	○	○	⊘	○	○	○
Fishes	⊘	⊘	○	○	○	○	○	○	○	○	○	○	○
Plankton	○	○	○	○	○	○	○	○	○	●	○	○	○
Benthos	○	○	○	○	⊘	○	○	○	○	○	○	○	⊘

birds, amphibians, mollusca and other biota in all freshwater systems. Finally, pesticides are also suspected of adversely affecting the diversity of a large number of other categories of biota (e.g., amphibians, mollusca, and emerging vegetation) although data are quite limited on these effects. Impacts in marine systems are less pronounced, although still substantial. Industrial discharges can result in substantial impacts to nearly all biota in estuarine and nearshore areas. The effects of pesticides on these systems are much less known other than representing a potentially substantial impact to birds in estuarine areas.

The information presented here suggests that toxic discharges in California could potentially represent a serious threat or substantial impact to biodiversity in freshwater systems and may present a substantial threat to biodiversity in marine ecosystems. It is important to note that as the magnitude and scope of these threats continue to increase, and as new threats continually appear, interactions between stressors will become more important. While currently not well studied or understood, interactions between two or more stressors could produce cumulative effects which are far more destructive than the individual threat alone. This suggests that although toxic-related threats to biodiversity often are not as serious as other factors (e.g., physical habitat alteration) they must be considered and addressed to ensure adequate protection of biodiversity.[73]

TOXIC REDUCTIONS AND POTENTIAL ECOLOGICAL BENEFITS OF THE CALIFORNIA TOXICS RULE

When the State of California implements the NPDES permit program, as well as other non-regulatory programs and activities, to achieve water quality standards, it is anticipated that ambient water quality will improve through reductions in the concentrations of toxics in California's aquatic systems. California's aquatic ecosystems include food webs of phytoplankton, invertebrates, fish, birds, mammals, and other organisms that interact with each other through a complex flow of matter and energy. Because of this linkage, toxic reductions in ambient waters that result in increased survival, growth, and reproductive fitness of individuals and populations should contribute to the health of other ecosystem components, including other species, populations, and communities.

Toxic reductions are anticipated for a variety of metals, pesticides, aromatics, trace elements, and chlorinated organic contaminants. Exposure of biota to these pollutants at levels exceeding the resulting water quality standard based on the proposed criteria may result in adverse ecological effects that will change or alter the structural or functional ability of the organism to survive, grow,

[73] Norse, 1990.

and reproduce. Adverse effects of many toxics include increased susceptibility to disease, reduced growth and development, altered physiology and behavior, impaired reproductive health and behavior, and if concentrations are high enough, death. Any one of these adverse effects can ultimately affect the survival, reproductive success, and overall health of a population, which may affect ecosystem health.

Because all components of ecosystems are linked to each other, improved survival, growth, productivity, and reproductive capacity of aquatic and terrestrial organisms should translate to improved ecosystem stability, resilience, and overall health. Specific improvements in ecosystem health following toxics reductions will depend on the interaction of a variety of factors, including: the timing, duration, and magnitude of baseline toxics exposure; the rate of toxics reduction attributable to achieving CTR-based water quality standards; the species assemblages present; the trophic structure of the system; the reproductive capacity and growth rate of susceptible and tolerant populations, and the availability of colonizing organisms.

Site-specific benefits for the entire State could not be quantified comprehensively because of the complexity, scale, and uncertainties of the interaction of the multitude of ecological systems and toxics to be affected by the proposed rule. However, ecological benefits from the proposed rule may be substantial because of the extensive variety, proportion, and geographic area of the affected aquatic systems, the diversity and uniqueness of California ecological resources, and the large number of toxics to be regulated under the CTR.

EPA concludes that the potential ecologic benefits associated with reducing toxics to meet CTR water quality criteria include:

- Reductions in toxics loadings are expected to contribute to improved conditions for fish spawning and/or migration in more than 223,000 acres of bays/harbors and estuaries, 102,000 acres of lakes, 1,000 miles of rivers and streams, and 11,000 acres of saline lakes.

- Potential bioaccumulatives of concern that currently threaten fish and wildlife throughout the State include selenium, mercury, PCBs, dioxins, and chlorinated pesticides. Mercury concentrations in California fish are estimated to reach levels that may be hazardous to piscivorous wildlife. Adverse effects on wildlife are also occurring as a result of exposure to selenium. Populations that may widely benefit from reduced concentrations include estuarine and freshwater fish and piscivorous animals, although current criteria may not be stringent enough to adequately protect some aquatic-dependant wildlife species.

- Reducing toxic contaminants to meet water quality criteria is expected to help contribute to improved conditions for the successful recovery of Federal and State threatened and endangered (T&E) species including species such as the Delta smelt, Desert pupfish, California brown pelican, Bald eagle, California clapper rail, California tiger salamander and western snowy plover. Statewide, T&E species may be at risk from toxics in approximately 180,000 acres of bays, harbors and estuaries, 2,000 river miles, and 230,000 acres of saline lakes.

- The greatest reductions in the likelihood of adverse toxics-related impacts on aquatic and terrestrial wildlife will accrue for the San Francisco Bay Watershed and the Central Valley. These areas have the greatest amount of toxic loadings and the greatest diversity and richness of species, populations, and communities.

- Reducing copper discharges to the Sacramento River to meet water quality criteria is likely to result in substantial protection for 90 percent or more of the organisms and communities that are currently adversely affected.

- Reduced concentrations of both selenium and pesticides in the waters that feed the Salton Sea are expected to contribute to improved conditions for the restoration and maintenance of currently declining populations of wildlife, including threatened and endangered species. These include the California brown pelican, peregrine falcon, bald eagle, Yuma clapper rail, and desert pupfish.

- All components of the ecosystem are linked to each other. Therefore, we expect that the improved water quality and likely associated improvements in survival, growth, and reproductive capacity of aquatic and terrestrial organisms resulting from reduced exposure to toxics will help to contribute to the increased stability, resilience and overall health of numerous ecosystems throughout California, and may contribute to protecting, restoring and maintaining California's rich biodiversity.

LIMITATIONS

The characterization of ecological benefits presented in this chapter is based on evaluation of indicators of specific effects, rather than detailed modeling and/or direct measurement of the proposed rule's impact on species, populations, and communities.

Because such modeling and measurement was beyond the scope of this effort, we cannot draw comprehensive conclusions about the proposed rule's effect on all the ecological benefits that may occur. The benefits described and presented here are only illustrative of the potential benefits of reducing toxics loadings to California's waters. The total benefits to organisms, populations, communities and ecosystems throughout the State are likely to be far greater than those benefits briefly described here and in Chapter 6.

Second, the proposed rule establishes criteria only for concentrations of pollutants in the water column, and for the most part does not directly address problems associated either with contaminated sediments or contaminants that have already entered the food web. The persistence of certain toxic pollutants in sediment and the tendency for many of the most persistent pollutants to bioaccumulate suggests that some of the benefits associated with decreased toxic loadings may not be realized immediately.

Third, there has been relatively little scientific research to date on chronic toxic effects to organisms as compared to acute effects. Data are extremely limited or not available on chronic effects for many species, particularly for organisms at lower trophic levels (e.g., phytoplankton and zooplankton). Consequently, some chronic aquatic life criteria have been established based on as few as five species data sets. In addition, aquatic life criteria are established to protect only 95 percent of the species. It is possible that the remaining five percent of the most sensitive species could be keystone species or species providing functions critical to the survival and health of other organisms and populations, and thus may not be fully protected. Finally, aquatic life criteria do not take into account potential synergistic effects of pollutants. As a result, there is considerable uncertainty concerning the type and range of ecological benefits likely to accrue from reducing chronic concentrations of toxics. Benefits could either be greater or less than those described here.

Finally, most assessment techniques and data collection efforts used to evaluate toxic impacts to ecosystems typically assess only isolated components of the ecosystem (usually organisms) rather than the interactions among ecosystem components. Species interactions among and between trophic levels are not considered in establishing water quality criteria, and have not been analyzed in detail in this report. In general, data are sparse on specific impacts to populations and communities from all toxic pollutants. Further, when population impacts are evaluated, they usually only describe impacts to higher trophic level consumers (e.g., birds and mammals). Consequently, the complete range of ecosystem benefits associated with meeting the proposed water quality criteria are not fully understood, and are probably understated in this analysis.

REFERENCES

Angermeir, P. and J.R. Karr, 1994, "Biological Integrity versus Biological Diversity as Policy Directives: Protecting Biotic Resources," *Bioscience* 44(4): 690-697.

Aquatic Habitat Institute, 1987. *An Assessment of the Loadings of Toxic Contaminants to the San Francisco-Bay Delta*, August..

Brown, Cynthia, 1996, "Effects of Chronic Metal Contamination in Suisun Bay on Resident Populations of Bivalves," in *3rd Biennial State of the Estuary Conference, October,* p. 17.

Cairns, 1983, in Cairns et al., 1992, Chapter 6, *Predicting Ecosystem Risk,* Princeton Scientific Publishing Company.

Cairns, J., B. Niederlehner, D. Orvos, eds., 1992, *Predicting Ecosystem Risk,* Princeton Scientific Publishing Co, Princeton, New Jersey.

Cairns, J., 1995, "Ecological Integrity of Aquatic Systems," *Regulated Rivers-Research & Management*, November, 11(3-4), 0313-0323.

California Environmental Protection Agency, 1994, *Water Quality Assessment*, State Water Resources Control Board, December 1994.

Cockerham, L.G., and B.S. Shane, eds., 1994, *Basic Environmental Toxicology*, CRC Press, Ann Arbor, Michigan.

Department of Fish and Game, State of California, 1991, *Annual Report on the Status of Calfornia State Listed Threatened and Endangered Animals and Plants.*

Department of Fish and Game, State of California, Natural Heritage Division, 1995, *Significant Natural Areas in California.*

Environmental Defense Fund & Bay Institute of San Franciso, June 1996, *Restoration of the San Francisco Bay-Delta-River System: Choosing Indicators of Ecological Integrity,* Prepared for the CalFed-Bay-Delta Program & U.S. Environmental Protection Agency.

Fry, Michael, 1996, "Organic Contaminants and Selenium: Implications for Waterfowl in the Bay," in *3rd Biennial State of the Estuary Conference,* October (p.18).

Harvey, T.E., K.J. Miler, R.L. Hothem, M.J. Rauzon, G.W. Page, and R.A. Keck, 1992, *Status and Trends Report on Wildlife of the San Francisco Estuary*, prepared by the U.S. Fish and Wildlife Service for the San Francisco Estuary Project, U.S. EPA, San Francisco, California.

Heinz, G.H., 1979, "Methylmercury: Reproductive and Behavioral Effects on Three Generations of Mallard Ducks," *J. Toxicol. Environ. Health*, 19:383-391.

Herbold, B., A.D. Jassby, and P.B. Moyle, 1992, *Status and Trends Report on Aquatic Resources in the San Francisco Bay Estuary*, Prepared by the San Franciso Bay Estuary Project, Oakland, California.

Herricks, E.E. and D.J. Schaeffer, 1987b, "Selection of Test Systems to Evaluate the Effects of Contaminants on Ecological Systems" as quoted in Schaeffer et al, 1988.

Kopec, A.D., J.T. Harvey, and M.L. Torok, 1995, *Toxic Pollutants, Health Indices, and Population Dynamics of Harbor Seals in San Franciso Bay*, Submitted to the San Francisco Estuary Project, Moss Landing Marine Laboratories, Moss Landing, California.

Larry Walker Associates, March 1993, *Pollution Problems Associated with Inactive Mines in the Sacramento River Basin.*

Luoma, Samuel N. and Phillips, D.J.H., 1988, "Distribution, Variability, and Impacts of Trace Elements in San Francisco Bay," *Marine Pollution Bulletin*, 19(9).

Luoma, S.N. and J.E. Cloern, 1982, "The Impact of Waste-water Discharge on Biological Communities in San Francisco Bay," Pages 137-160. In *San Francisco Bay: Use and Protection* (Eds), W.J. Kockelman, T.J. Conomos, and A.E. Leviton. Pacific Divison, American Association for the Advancement of Science, San Francisco, California.

McLandress, M.R., 1983, "Sex, Age, and Species Differences in Disease Mortality of Ross' and Lesser Snow Geese in California: Implications for Avian Cholera Research," *Calif. Fish and Game* 69(4): 196-206.

Moyle, Peter, 1994, *Life on the Edge*, Volume I: Wildlife, p. 159-160.

Moyle, P.B. and J. E. Williams, 1990, "Biodiversity Loss in the Temperate Zone: Decline of the Native Fish Fauna of California," *Conservation Biology*, 4:475-484.

NOAA, 1992, as cited in Pease, 1995, p. 28.

Norse, Elliot, 1990, *Threats to Biological Diversity in the United States*, Prepared for U.S. EPA, Office of Policy, Planning & Evaluation.

Odum, E.P. 1985, "Trends Expected in Stressed Ecosystems, " *BioScience* 35(7, July-August): 419-422.

Odum, Eugene P., 1993, *Ecology and Our Endangered Life-Support Systems*, Sinauer Associates, Inc., Publishers, Sunderland, Massachusetts.

Ohlendorf, H.M. and W.J. Fleming, 1988, "Birds and Environmental Contaminants in San Franciso and Cesapeake Bays," *Marine Pollution Bulletin* 19(9):487-495.

Pease, William, 1995, *Pesticide Impacts on California Ecosystems* (Draft), California Policy Seminar, Berkeley, California.

Rapport, D.J., H.A. Regier, T.C. Hutchinson. 1985, "Ecosystem Behavior Under Stress," *American Naturalist*, 125:617-640.

Rapport, D. (Ed), 1995, *Evaluating and Monitoring the Health of Large Scale Ecosystems*, NATO ASI Series/Springer Verlag, New York, 454 pages, ISBN 3-540-58805-1.

Rasmussen, 1994, *Users Guide for California's Toxic Substance Monitoring Program Database, CALEPA.*

Richter, Brian, David Braun, Michael Mendelson, Lawrence Master, 1997. "Threats to Imperiled Freshwater Fauna," *Conservation Biology*

San Francisco Estuary Institute, *1994. San Francisco Estuary Regional Monitoring Program for Trace Substances: 1993 Annual Report*, December.

Sanders, J.G. and S.J. Cibik, 1988, "Response of Chesapeake Bay Phytoplankton Communities to Low Levels of Toxic Substances," *Marine Pollution Bulletin*, 19(9): 439-444.

Schaeffer, D.J., EE Herricks, H.W. Kerster, 1988, "Ecosystem Health: 1, Measuring Ecosystem Health," *Environmental Management*, 12:445-455.

Schindler, D.W. 1987, "Detecting Ecosystem Responses to Anthropogenic Stress," *Canadian Journal of Fisheries and Aquatic Sciences*, 44:6-25.

Schwarzbach, S. 1996, *Mercury and Clapper Rail Hazards, SEATAC Conference*.

Setzler-Hamilton, Eileen, J.A. Whipple, R.B. MacFarlane, 1988, "Striped Bass Populations in Chesapeake and San Francisco Bays: Two Environmentally Impacted Estuaries," *Marine Pollution Bulletin*, 19,(9), P. 466-477.

Skorupa, J, 1993, as quoted in Draft Letter of U.S. FWS Intent to Testify for the Water Quality Standards for Interstate and Intrastate Streams in New Mexico, September 27, 1993, Jennifer Fowler-Propst, author.

Smith, G.J. and A.R. Flegal, 1993, "Silver in San Francisco Bay Estuarine Waters," *Estuaries*, 16(3A):547-558.

Solomon, D.R., D.B. Baker, R.P. Richards, K.R. Dixon, S.J. Klaine, T.W. La Point, R.J. Kendall, C.P. Weisskopf, J.M. Giddings, J.P. Giesy. L.W. Hall, Jr., and M. Williams, 1996, "Ecological Risk Assessment of Atrazine in North American Surface Waters," *Environ. Toxicol. Chem.* 15(1):31-76.

Steinhart, Peter, 1994, *California's Wild Heritage: Threatened and Endangered Animals in the Golden State*, Sierra Club Books.

Tompson, Janet et al, 1996. "Response of Potamocorbula amurensis to Riverine Inputs and Pollutants in Suisan Bay," in *3rd Biennial State of the Estuary Conference*, October, (p. 53).

U.S EPA, 1985a, *Aquatic Criteria.*

U.S EPA, 1991. *Estimation of Waterborne Concentrations of Contaminants that are Thresholds for Adverse Effects in Wildlife: Selenium.* Office of Research and Development, Corvallis, Oregon, June.

U.S. EPA, 1994. *Mercury Study Report to Congress, Volume VI: Characterization of Human Health and Wildlife Risks from Anthropogenic Mercury Emissions in the United States, Draft,* Office of Air Quality Planning and Standards and Office of Research and Development, December 12.

U.S. EPA, 1994, *Regulatory Impact Assessment of the Final Water Quality Standards for the San Francisco Bay/Delta and Critical Habitat Requirements for the Delta Smelt,* Region IX, San Francisco California, December.

U.S. Environmental Protection Agency, March 1995. *Regulatory Impact Analysis of the Final Great Lakes Water Quality Guidance: Final Report.*

U.S. EPA, April 1995. *Regulatory Impact Assessment of Proposed Effluent Limitations Guidelines and Standards for the Metal Products and Machinery Industry (Phase I).*

U.S. EPA, 1997, *Potential Benefits of a Selenium Criterion to Protect Wildlife in California,* Office of Sustainable Ecosystems and Communities, Office of Policy, Planning and Evaluation, Washington, DC.

U.S. Fish and Wildlife Service, May 1992. *An Overview of Irrigation Drainwater Techniques, Impacts on Fish and Wildlife Resources, and Management Options.*

U.S. Fish and Wildlife Service, 1997, *California Toxics Rule Endangered Species Act Consultation, Effect Determination Matrix,* Submitted to U.S.EPA, Region IX, San Francisco, California.

U.S. Geological Survey, 1990. *Reconnaissance Investigation of Water Quality, Bottom Sediment, and Biota Associated with Irrigation Drainage in the Salton Sea Area, California, 1986-87.*

U.S. Geological Survey, 1993. *Detailed Study of Water Quality, Bottom Sediment, and Biota Associated with Irrigation Drainage in the Salton Sea Area, California, 1988-1990.*

Westman, Walter E., 1985, *Ecology, Impact Assessment, and Environmental Planning,* John Wiley and Sons.

Wilcove, J.E., and M.J. Bean, editors, 1994, *The Big Kill,* Environmental Defense Fund, Washington, DC.

Wilcox, B.A., 1984, "In situ Conservation of Genetic Resources: Determinants of Minimum Area Requirements," In *National Parks: Conservation and Development,* eds, J.A. Neeley, and K.R. Miller, pp. 639-647, Smithsonian Institution Press, Washington, DC.

Wobeser G., N.D. Nielsen, and B. Schiefer, 1976, "Mercury and Mink II: Experimental Methyl Mercury Intoxication," *Can. J. Comp.* Med. 40: 34-45.

Young, George et al., 1994."Histopathology, blood chemistry, and physiological status of normal and moribund striped bass (Morone Saxatilis) involved in summer mortality ('die-off') in the Sacramento-San Joaquin Delta of California," *Journal of Fish Biology,* 44, 491-512.

REFERENCES FOR EXHIBIT 5-10

Di Giulio, R.T. and Scanlon, P.F. 1984. Heavy metals in tissues of waterfowl from the Chesapeake Bay, USA. *Environ. Pollut. (Ser. A)* 35: 29-48.

Heinz, G.H. 1979. Methylmercury: reproductive and behavioral effects on three generations of mallard ducks. *J. Wildl. Manage.* 43: 394-401.

Heinz, G.H., Hoffman, D.J., Krynitsky, A.J., and Weller, D.M.G. 1987. Reproduction in mallards fed selenium. *Environ. Toxicol. Chem.* 6: 423-433.

Hoffman, D.J., Rattner, B.A., Bunck, C.M., Krynitsky, A., Ohlendorf, H.M., and Lowe R.W. 1986. Association between PCBs and lower embryonic weight in black-crowned night heron in San Francisco Bay. *J. Toxicol. Environ. Health.* 19: 383-391.

Gochfeld, M. and Burger, J. 1987. Heavy metal concentrations in the liver of three duck species: influence of species and sex. *Environ. Pollut.* 45: 1-15.

King, K.A., and Cromartie, E. 1986. Mercury, cadmium, lead, and selenium in three waterbird species nesting in Galveston Bay, Texas, USA. *Colonial Waterbirds.* 9: 90-94.

Ohlendorf, H.M., Custer, T.W., Lowe, R.W., Rigney, M., and Cromartie, E. (In press a) Organochlorines and mercury in eggs of coastal terns and herons in California, USA. *Colonial Waterbirds.*

Ohlendorf, H.M., Hothem, R.L., Aldrich, T.W., and Krynitsky, A.J. 1987. Selenium contamination of the Grasslands, a major California waterfowl area. *Sci. Total Environ.* 66: 169-183.

Ohlendorf, H.M., Klaas, E.E., and Kaiser, T.E. 1978. Environmental pollutants and eggshell thinning in the black-crowned night heron. In *Wading Birds* (A. Sprunt, IV, J.C. Ogden, and S. Winckler, eds.), pp. 63-82. National Audubon Society Research Report No. 7.

Ohlendorf, H.M., Klaas, E.E., and Kaiser, T.E. 1979. Environmental pollutants and eggshell thickness: anhingas and wading birds in the eastern United States. Special Scientific Report -- Wildlife No. 216. U.S. Fish and Wildlife Service.

Ohlendorf, H.M., Lowe, R.W., Kelly, P.R., and Harvey, T.E. 1986c. Selenium and heavy metals in San Francisco Bay diving ducks. *J. Wildl. Manage.* 50: 64-71.

Ohlendorf, H.M., Marois, K.C., Lowe, R.W., Harvey, T.E., and Kelly, P.R. Environmental contaminants and diving ducks in San Francisco Bay. Symposium on selenium and agricultural drainage implications for the environment (Selenium IV) Berkeley, California.

Ohlendorf, H.M. and Miller, M.R. 1984. Organochlorine contaminants in California Waterfowl. *J. Wildl. Manage.* 48: 867-877.

Ohlendorf and Fleming, 1988. Hazard Evaluation of Environmental Contaminants in Bird Tissues or Eggs from San Francisco Bay Delta.

Presser, T.S., and Ohlendorf, H.M. 1987. Biogeochemical cycling of selenium in the San Joaquin Valley of California. *Environ. Manage.* 11: 805-821.

Vermeer, K., and Peakall, D.B. 1979. Trace metals in seaducks of the Fraser River Delta intertidal area, British Columbia. *Mar. Pollut. Bull.* 10: 189-193.

White, D.H and Cromartie, E. 1985. Bird use and heavy metal accumulation in waterbirds at dredge disposal impoundments, Corpus Christi, Texas. *Bull. Environ. Contam. Toxicol.* 34: 295-300.

White, D.H., Hofmann, P.S., Hammond, D., and Baumgarten, S. 1988. *Selenium Verification Study, 1986-87: A Report to the State Water Resources Control Board.* California Department of Fish and Game, Sacramento.

CASE STUDIES OF ECOLOGICAL BENEFITS CHAPTER 6

INTRODUCTION

This chapter provides a more detailed description of the range of ecological benefits expected to occur when toxic pollutant discharges are reduced to meet the proposed water quality criteria for the State of California. The chapter presents case studies of two areas: the San Francisco Bay Estuary and the Salton Sea.

Because of time and data constraints, it was not possible to perform a comprehensive assessment of the benefits of the California Toxics Rule for these two areas. As an alternative, we have evaluated a range of qualitative and quantitative indicators and other relative measures of potential ecosystem benefits. We rely primarily upon selected constituent-specific data for these two sites, using these data to identify potential benefits at the individual, population, and community level (e.g., decreased mortality rates, enhanced breeding success, increased productivity); where possible, we also discuss higher trophic level impacts. The limitations of this approach are similar to those described in Chapter 5.

SAN FRANCISCO BAY

The San Francisco Bay Estuary is the largest estuary on the west coast of the Americas. It is a highly productive and valuable ecosystem supporting a diversity of plants and animals. It is also an important economic and recreational resource that is heavily affected by the activities of the nearly 12 million people who live in the Bay area. An estimated 5,000 to 40,000 tons of over 60 different toxic pollutants enter the Bay daily from more than 50 sewage treatment plants, more than

65 industrial facilities, and a range of nonpoint sources.[1] The introduction of these pollutants into the ecosystem poses a range of risks. This case study describes these risks and discusses the potential ecological benefits of reducing toxic pollution inputs to the San Francisco Bay Estuary. The case study's key findings include the following:

- Toxic contaminants such as mercury, selenium, PCBs, pesticides, cadmium, and copper have been observed in San Francisco Bay waters, sediments and organisms at hazardous levels. Scientific data indicate that animals chronically exposed to these pollutants can experience numerous adverse effects.

- Reductions in chronic exposures to toxic pollutants are expected to improve the reproduction, growth, general health, and survival of Estuary biota. In particular, many species that migrate through the Bay - including chinook salmon, striped bass, and waterfowl - may benefit from improved breeding habitat.

- Reductions in cumulative toxic loadings to sediments reduce the possibility of resuspension of toxics in the water column. Filter-feeding animals such as clams and other mollusks, which take in suspended solids when feeding, are among those most likely to benefit from such reductions.

- Reduced toxic inputs to the Bay could improve habitat and enhance lower trophic-level food supplies, with the potential for contributing to improved conditions necessary for the recovery of threatened and endangered species like the California clapper rail, California brown pelican, and American peregrine falcon.

- Improved water quality conditions in the Bay may also reduce the bioaccumulation of toxic pollutants in upper trophic levels. It has been found that upper level predators in the San Francisco Bay Estuary acquire pollutants of concern through food-web transfer. Predator species that most likely would benefit from better control of toxics include predatory fish and piscivorus birds, as well as harbor seals and other piscivorus mammals.

---

[1] This discussion is based upon information provided in two documents: San Francisco Estuary Project, *1992 State of the Estuary*, U.S. EPA and the Association of Bay Area Governments; and California Regional Water Quality Control Board, *Water Quality Control Plan, San Francisco Bay Basin, Region 2*, 1986.

- Because all components of the ecosystem are linked, the improved survival, growth, productivity, and reproductive capacity of aquatic and terrestrial organisms resulting from reduced exposure to toxics should contribute to the increased stability, resilience and overall health of the Bay, and help to maintain and improve the rich biodiversity of the Estuary.

The remainder of this chapter discusses the geographic setting of the San Francisco Bay Estuary, its biological resources, the extent to which these resources have been affected by toxic pollutants, and the potential benefits of reducing concentrations of toxic pollutants in the Bay.

Geographic Setting

California's Region 2, the San Francisco Bay Region, extends over approximately 1,620 square miles of the state's central coast. Figure 6-1 shows the location of major water bodies in this region. As the figure shows, the region is dominated by the San Francisco Bay Estuary, a complex of several interconnected water bodies that includes Suisun Bay, Carquinez Strait, San Pablo Bay, Central Bay, and South Bay. Together these bays cover approximately 470 square miles, or about 30 percent of the area of Region 2, and represent the largest coastal embayment on the Pacific coast of the United States. Additional detail on the waters that comprise the San Francisco Bay Estuary is provided below.

- Suisun Bay is an important nursery ground for several fish species. As the site of an entrapment zone, where high densities of food are brought in from tidal and freshwater flows, Suisun Bay supports large numbers of zooplankton, juvenile fish, and small fish species.[2] In addition, the Bay is bordered by Suisun Marsh, the largest brackish marsh in the United States, covering approximately 57,000 acres.

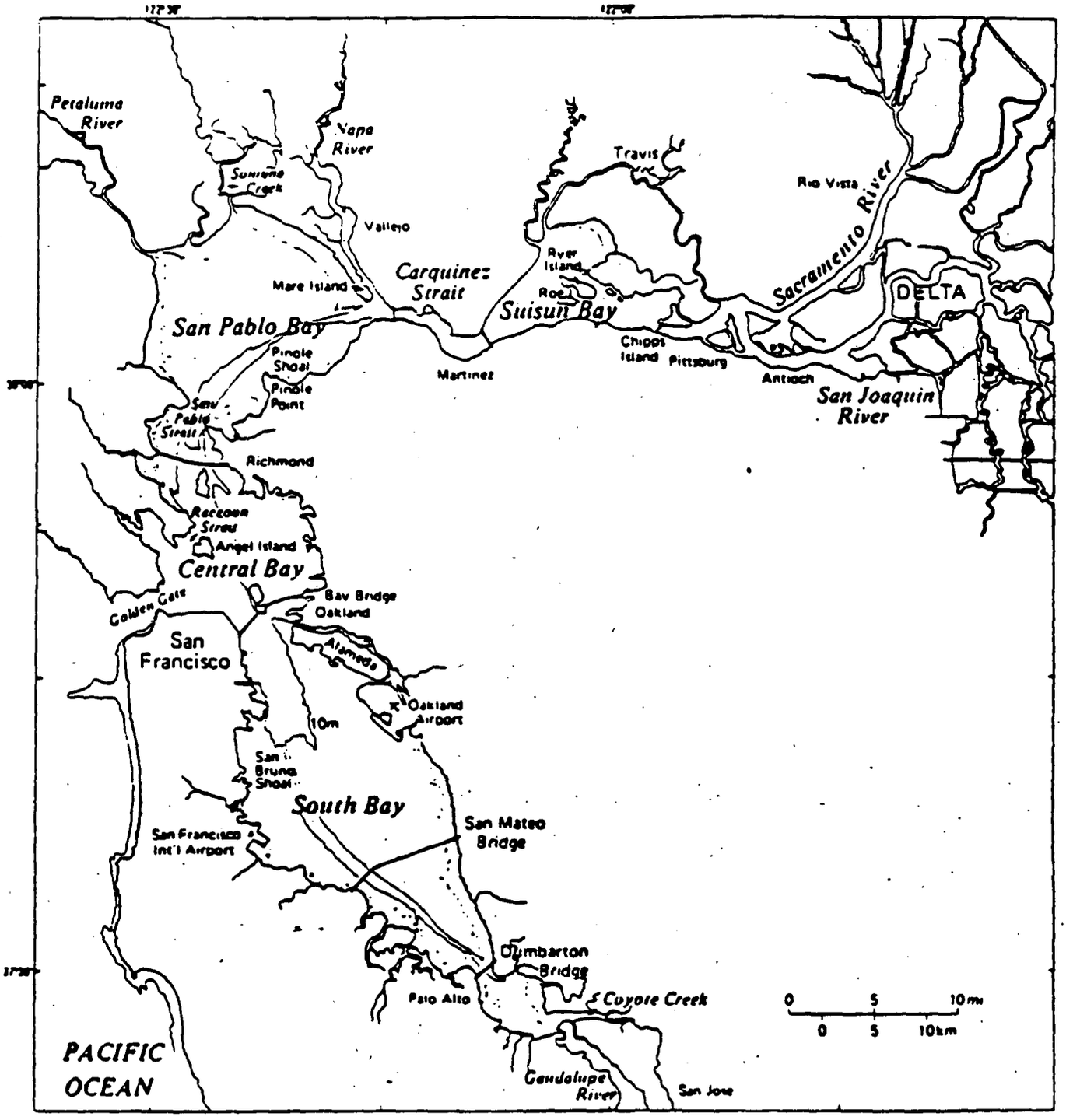
- Carquinez Strait is a deep, narrow, 12-mile channel that connects Suisun Bay and San Pablo Bay. It averages 29 feet in depth and is characterized by strong currents. It also serves as a U.S. Army Corps of Engineers' dredged material disposal site. The Strait's strong currents often carry dredge spoils into other areas of the Estuary.

- San Pablo Bay is a large and open bay that averages nine feet in depth. It has extensive shallows, salt ponds, and a significant riverine freshwater inflow causing euryhaline conditions (i.e., a wide range in salinity). Few marine fish

[2] Herbold, 1992.

Figure 6-1

MAP OF SAN FRANCISCO BAY ESTUARY AND DELTA



inhabit this embayment because of the variations in salinity, but the bay provides an important passage for migratory fish and a nursery area for Dungeness crabs. In addition, many migratory waterfowl, shorebirds, and other birds utilize the habitat the Bay provides. Like Carquinez Strait, San Pablo Bay is also a major dredge spoil site.[3]

- Central Bay stretches between San Pablo Bay and the Oakland-San Francisco Bay Bridge. It includes the deepest waters in San Francisco Bay, averaging 35 feet in depth, and is directly affected by marine currents that flow through the Golden Gate.

- South Bay includes the remainder of San Francisco Bay south of the Oakland-San Francisco Bay Bridge. It is comprised of extensive shallow areas, salt evaporation ponds, marshes, and mudflats, particularly at its southern tip.[4] The southernmost portion of South Bay, referred to in this report as the extreme South Bay, has a fairly constant salinity and is essentially a shallow tidal lagoon with a long residence time, particularly during periods of low flow.[5] During dry periods it receives most of its freshwater inputs from sewage treatment discharges.[6] The extreme South Bay is also characterized by daytime high tides that promote high organic productivity and rapid benthic organism growth. This growth is important in providing food sources for higher organisms in the Estuarine food chain.[7]

A number of rivers and more than 175 streams drain to the Bay. Among the more significant are the Sacramento and San Joaquin Rivers of the Delta, the Napa River to the north, and the Guadalupe River and Alameda Creek to the south. In total, the San Francisco Bay Estuary drains more than 40 percent of California's land area.

---

[3] Herbold, 1992.

[4] Herbold, 1992.

[5] U.S. EPA, 1992. *State of the Estuary: A Report on the Conditions and Problems in the San Francisco Bay/Sacramento - San Joaquin Delta Estuary*, Region 9 (June).

[6] Luoma and Phillips, 1988.

[7] Herbold, 1992.

Biological Resources

An estuary is defined as a partially enclosed body of water that interfaces a fresh water source with tidal ocean water. This transition zone between salt and freshwater results in a variety of diverse habitats that support a plethora of biological resources, and creates one of the richest and most productive types of ecosystems. The San Francisco Bay Estuary has been designated a National Priority Estuary under Section 320 of the Federal Clean Water Act, a designation based in part upon its ecological importance. The Bay supports approximately 120 fish species, 380 species of wildlife (including 255 species of birds, 14 species of amphibians, 30 species of reptiles, and 81 species of mammals), more than 200 species of zooplankton, hundreds of species of phytoplankton, countless numbers of benthic organisms, and a wide variety of plant life.[8]

Exhibit 6-1 presents a partial list of biota found in different areas of the Bay, reflecting the diversity of the ecosystem. For example, the Bay is a major haul-out and pupping area for harbor seals (see Figure 6-2).[9] In addition, the area is a stopover for approximately half of the migrating shorebirds and waterfowl that travel the Pacific Flyway, with the San Francisco National Wildlife Refuge, located along South Bay, offering particularly important migratory bird habitat.[10] More than a million waterfowl (see Figure 6-3) utilize the Bay as a staging and wintering area on their migration routes. The Bay is also an important shorebird staging area (see Figure 6-4), and has been designated as having hemispheric importance for this purpose by the Western Hemisphere Shorebird Reserve Network, a recognition given to only three other sites on the western shores of the Americas (see Figure 6-5).[11] Resident and migratory bird species common to the Bay area include avocets, stilts, plovers, sandpipers, phalaropes, grebes, pelicans, cormorants, herons, egrets, gulls, canvasbacks, greater scaup, lesser scaup, and surf scoter.[12]

---

[8] USEPA, 1992.

[9] Kopec et al., 1994. Harbor seals utilize estuarine sand and mudflats for birthing and rearing pups. These areas are isolated and undisturbed and provide abundant food sources. However, these environments also expose the seals to highly polluted areas associated with coastal urban activities.

[10] USEPA, 1992. The Pacific Flyway is a major bird migratory route that extends from Alaska and Canada south along the U.S. west coast into Mexico. It covers approximately 25 percent of the continental United States and provides passage for countless waterfowl and shorebirds.

[11] USEPA, 1992. The Western Hemisphere Shorebird Reserve Network is a collaborative effort formed by the World Wildlife Fund, the International Association of Fish & Wildlife Agencies, and the Academy of Natural Sciences of Philadelphia that coordinates agencies, conservation groups and other organizations in efforts to protect migratory shorebirds. Sites declared to be of hemispheric importance host at least 500,000 shorebirds annually or 30 percent of a species' flyway population.

[12] USEPA, 1992.

Exhibit 6-1

REPRESENTATIVE SPECIES FOUND IN SAN FRANCISCO BAY REGION

Bay	Constituents of Concern	Species		Habitat
Suisun	Nickel Selenium Chromium sources Pesticides Metals	Delta Smelt Longfin Smelt Striped Bass Yellowfin Goby Opossum Shrimp Zooplankton Juvenile/small fish Sacramento Splittail Waterfowl Peregrine Falcon	Asian Clam Dabbling Ducks Geese Tundra Swan Cranes White Sturgeon Tule Perch Mussel Suisun Shrew	Nursery for young of year fish Entrapment Zone marshes Open water Tidal salt marshes Brackish marshes
San Pablo	Selenium	Striped Bass Starry Flounder Longfin Smelt Yellowfin Goby Migratory Birds Dungeness Crab American Avocet	Scaup Scoter Canvasback Ruddy Duck Northern Shoveler Harbor Seal CA Brown Pelican Suisun Shrew	Shallows Large freshwater inflow Open water Intertidal mudflats Rocky shore Tidal salt marshes Brackish marshes
Central	PCBs Silver Selenium Chromium	Chinook Salmon American Shad Pacific Herring Harbor Seal Loons Peregrine Falcon	English Sole Northern Anchovy Pacific Pompano CA Brown Pelican Starry Flounder White Croaker	Deepwater High velocity water flow Open water Rocky shore Tidal marsh
South	Copper Nickel Silver Zinc Selenium Mercury Cadmium Arsenic	Northern Anchovy Bay Goby Bat Rays Walleye Surfperch Harbor Seal Brown Smoothhound Eared Grebe Surf Scoter	Surf Perch White Croaker CA Clapper Rail Salt Marsh Harvest Mouse Clams American Avocet Topsmelt	Salt ponds Tidal marshes Freshwater inflow Intertidal mudflat
Entire San Francisco Bay	PCBs Trace elements DDT Mercury Dieldrin Dioxin Furans	Horned Grebe Diving Ducks Dabbling Ducks	Snowy Egret Shorebirds Snowy Plover	

Sources: Herbold et al., 1992; Harvey et al., 1992; Moore, 1995; Kopec and Harvey, 1995; Ohlendorf and Fleming, 1988; State WQA database.

Figure 6-2

HARBOR SEAL CAPTURE, HAUL-OUT SITES, AND FEEDING AREAS IN THE SAN FRANCISCO BAY AREA

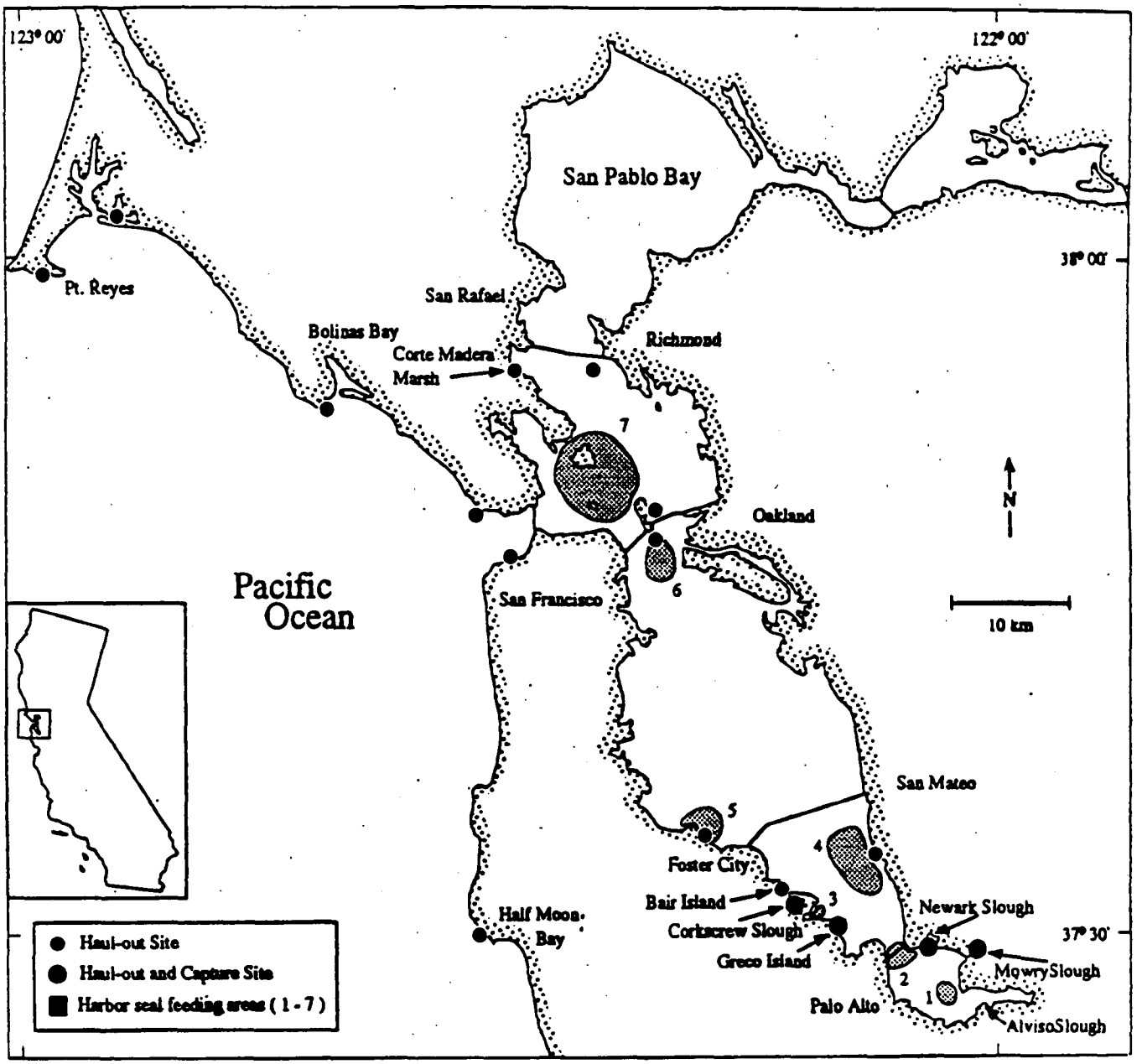


Figure 6-3

AVERAGE RELATIVE COMPOSITION OF WATERFOWL SPECIES IN THE SAN FRANCISCO BAY ESTUARY 1987-1990

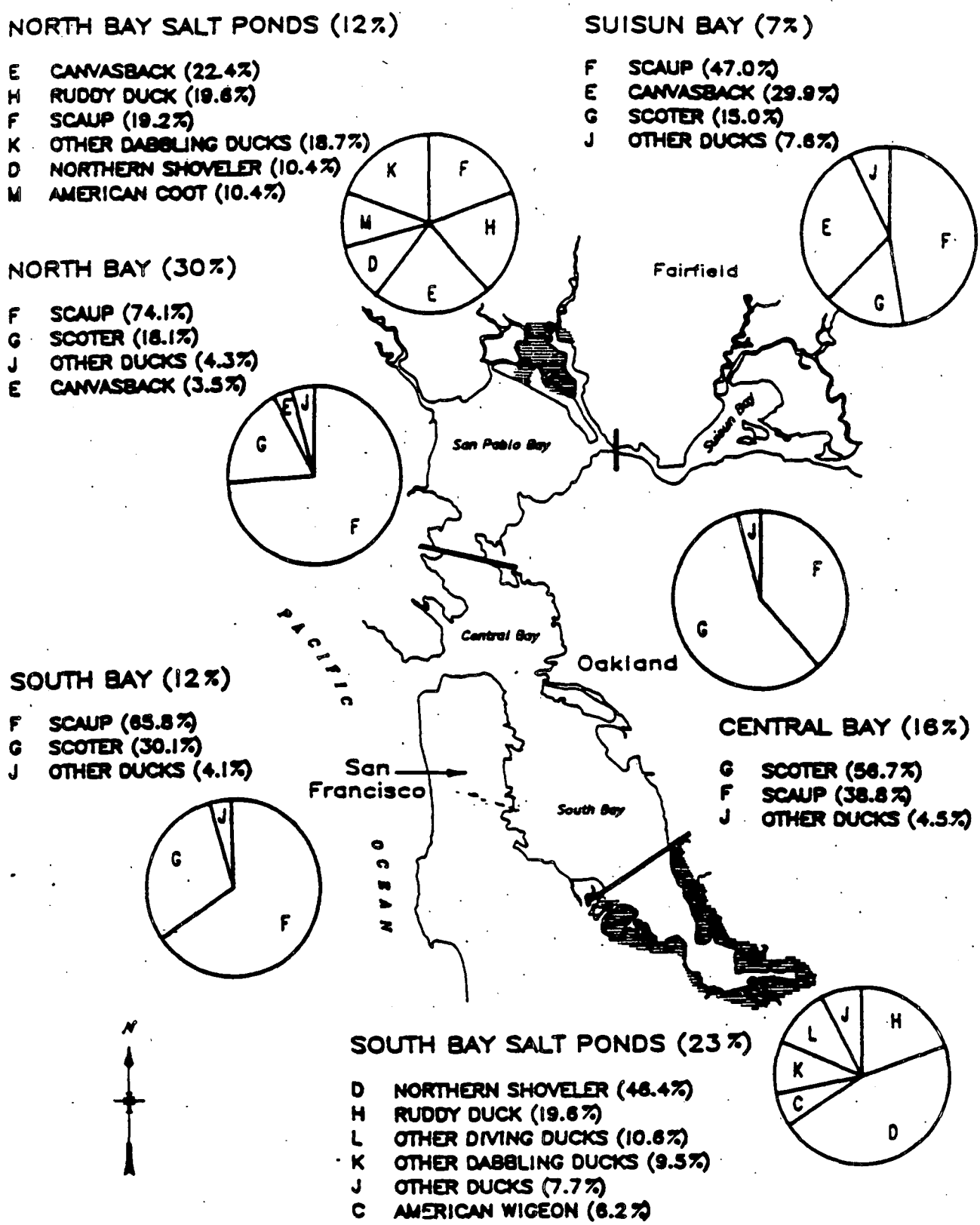


Figure 6-4

Shorebird Use of San Francisco Bay

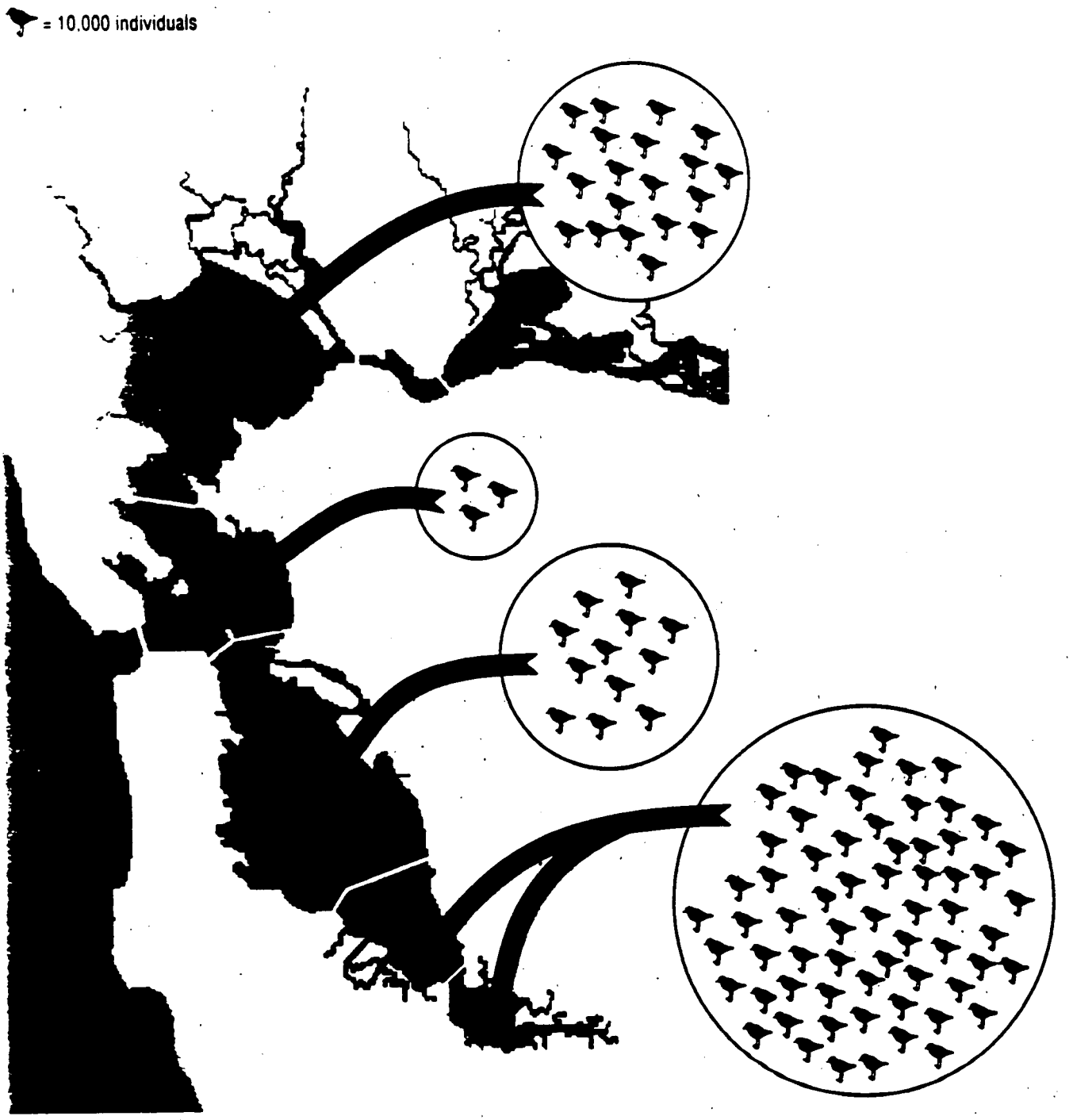
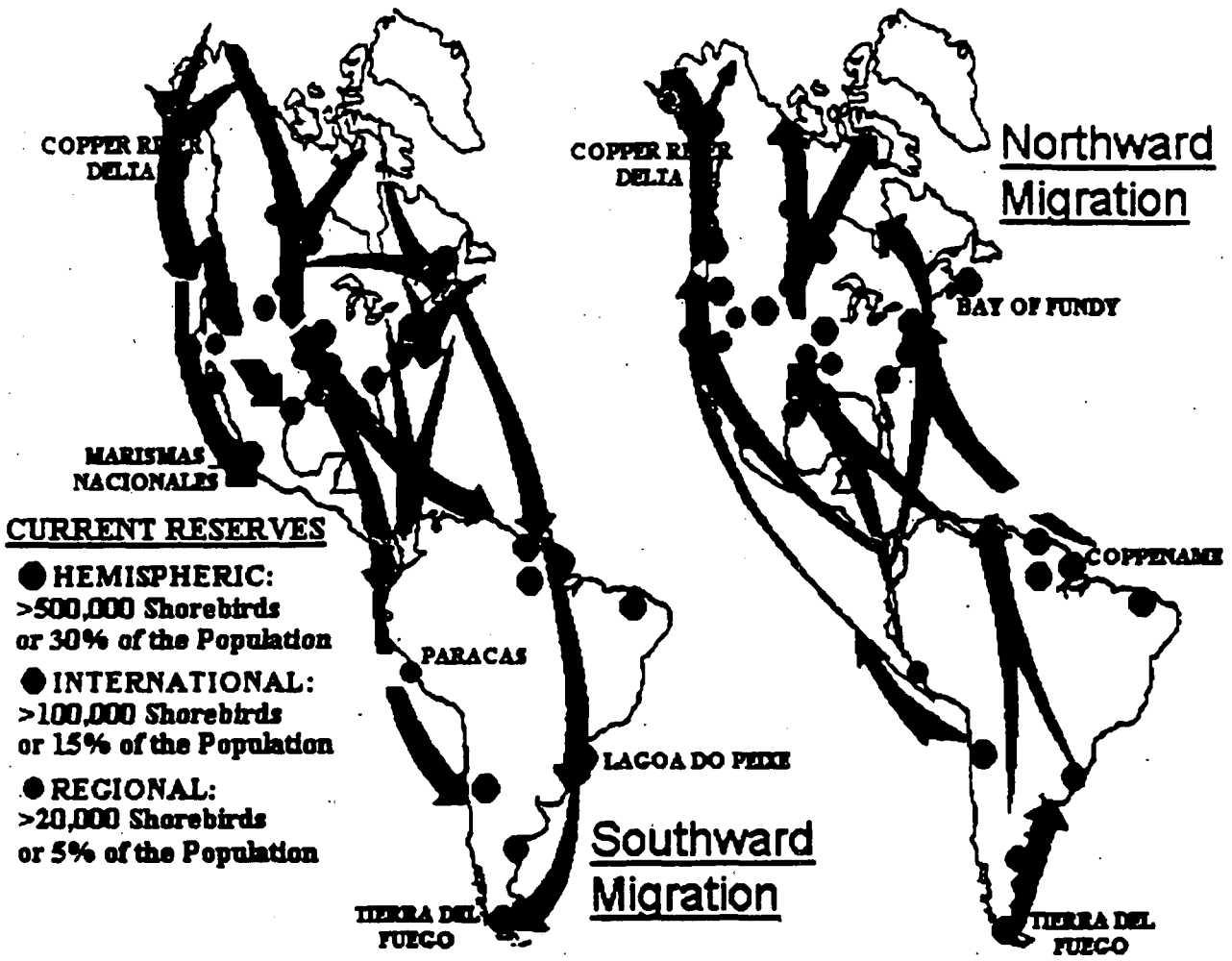


Figure 6-5

SHOREBIRD MIGRATION PATTERNS OF THE WESTERN HEMISPHERE



In addition to providing important habitat for birds and mammals, the San Francisco Bay Estuary supports a broad range of fish species and a large sport fishery, with striped bass, sturgeon, American shad, white catfish, and starry flounder among the sport fish most popular with recreational anglers. The region was also once the site of a rich and diverse commercial fishery, including sardine, herring, smelt, sole, salmon, flatfish, white sturgeon, flounder, anchovy, steelhead trout, crustaceans, and mollusks. Today, the only fish commercially harvested directly from the Bay are Pacific herring, Northern anchovy, and Bay shrimp; however, many commercially important fish species continue to rely upon the estuary as a nursery ground, spawning area, migration route, and feeding area. For example, two-thirds of California's migratory salmon, which are highly valued as both a sport and commercial species, pass through the Bay on their journey to and from upstream spawning grounds. In addition, more than 100 non-sport or non-commercial fish species inhabit the Bay.

Of additional note in profiling the biota of the San Francisco Bay Estuary are the relatively large number of rare, threatened, or endangered species that inhabit the region. As shown in Exhibit 6-2, members of several federally listed endangered animal species - including piscivorus birds like the Bald eagle, California brown pelican, or American peregrine falcon, shorebirds like the California clapper rail and California least tern, mammals like the Salt marsh harvest mouse, and fish like the Delta smelt - rely directly or indirectly upon the habitat the Estuary provides.[13] Figure 6-6 further illustrates this point, identifying locations at which state or federally listed threatened or endangered species have been sighted. As the exhibit and map suggest, there is significant potential for the quality of the Bay's waters to affect area populations of threatened or endangered species.

Nature of Toxics Impairment

The water resources of Region 2 are among the most heavily affected by toxic pollution in the state of California. As described in Chapter 2, over two-thirds of the region's bays, 60 percent of its wetland areas, and 39 percent of its rivers and streams are affected by toxics.[14] According to California's 303(d) list, a number of the water bodies adversely affected by toxics in Region 2 are of significant priority for the state.[15] Exhibit 6-3 presents information on these water bodies, which include all major sections of San Francisco Bay and the Suisun Marsh wetlands, as well as several of the rivers that discharge to the Bay. California's Bay Protection and Toxic Cleanup Program (BPTCP) provides further data on key water bodies affected by toxic pollutants. The known toxic

---

[13] USEPA. 1994.

[14] As elsewhere in this report, we classify as affected by toxics those waters that have been assessed and rated by the State of California as of medium or poor water quality due, in whole or in part, to contamination by toxic pollutants.

[15] California Report on Impaired Surface Waters, Clean Water Act Section 303(d), May 1994.

Exhibit 6-2

SPECIES OF CONCERN IN THE SAN FRANCISCO BAY ESTUARY REGION

Species	Status	Location	Habitat
Greater sandhill crane	ST	Delta	brackish/freshwater, seasonal marshes
Bald eagle	FE, SE	northern and eastern periphery of estuary	open water, brackish & freshwater marshes
California Brown Pelican	FE, SE	Central and San Pablo Bays	open water, salt ponds
Aleutian Canada goose	FT, SE	Suisun Marsh	seasonal marshes, farmed wetlands, grasslands
American peregrine falcon	FE, SE	South and North Bays, Suisun Marsh, Delta	salt, brackish & freshwater marshes
Black rail	ST, FC1	North Bay, Suisun Marsh	salt marshes
California clapper rail	FE, SE	South and North Bays, Suisun Marsh	salt marshes
Western snowy plover	FC2, SSC	entire bay (nesting in South Bay only)	salt ponds
California least tern	FE, SE	South and North Bays, Suisun Marsh	salt ponds, sandy bayshore
Alameda song sparrow	FC2, SSC	South Bay	salt marshes
San Pablo song sparrow	FC2, SSC	San Pablo	salt marshes
Suisun song sparrow	FC2, SSC	Suisun Bay	salt marshes
Salt marsh harvest mouse	FE, SE	South and North Bays, Suisun Marsh	salt marshes
Salt marsh wandering shrew	FC1, SSC	South Bay	salt marshes
Suisun ornate shrew	FC1, SSC	Grizzly Island	salt marshes
Delta Smelt	FE	Suisun Bay, Delta	Suisun Bay - river channels, open water and shoals
Winter-run chinook salmon	FE	South and North Bays, Suisun Marsh, Delta	open waters to Delta
Longfin smelt	Species of concern	San Pablo, Suisun, South and Central Bays, Delta	brackish water
Spring-run chinook salmon	Species of concern	Central, San Pablo, Suisun Bays, Delta	open water, up to and through Delta
Sacramento splittail	Species of concern	Suisun Marsh	salt marshes
Green sturgeon	Species of concern	San Pablo, Suisun Bays	open water, brackish water

FE = federal endangered
FT = federal threatened
SE = state endangered
ST = state threatened
SSC = species of state concern

FC = federal candidate for listing
Cat 1 = Taxa for which the USFWS has sufficient biological information to support a proposal to list as endangered or threatened.
Cat 2 = Taxa for which existing information may warrant listing, but for which substantial information to support a proposed rule is lacking.

Sources: USEPA. 1994. *Regulatory Impact Assessment of the Final Water Quality Standards for the San Francisco Bay/Delta and Critical Habitat Requirements for the Delta Smelt.* December 15, 1994. San Francisco, CA. With technical assistance from Jones & Stokes Associates, Inc. Sacramento, CA (JSA 94-130).
San Francisco Estuary Project. 1992. *State of the Estuary.* San Francisco, CA.
Herbold, B., A.D. Jassby, and P.B. Moyle. 1992. *Status and Trends Report on Aquatic Resources in the San Francisco Estuary.* San Francisco Estuary Project. Oakland, CA.

Figure 6-6

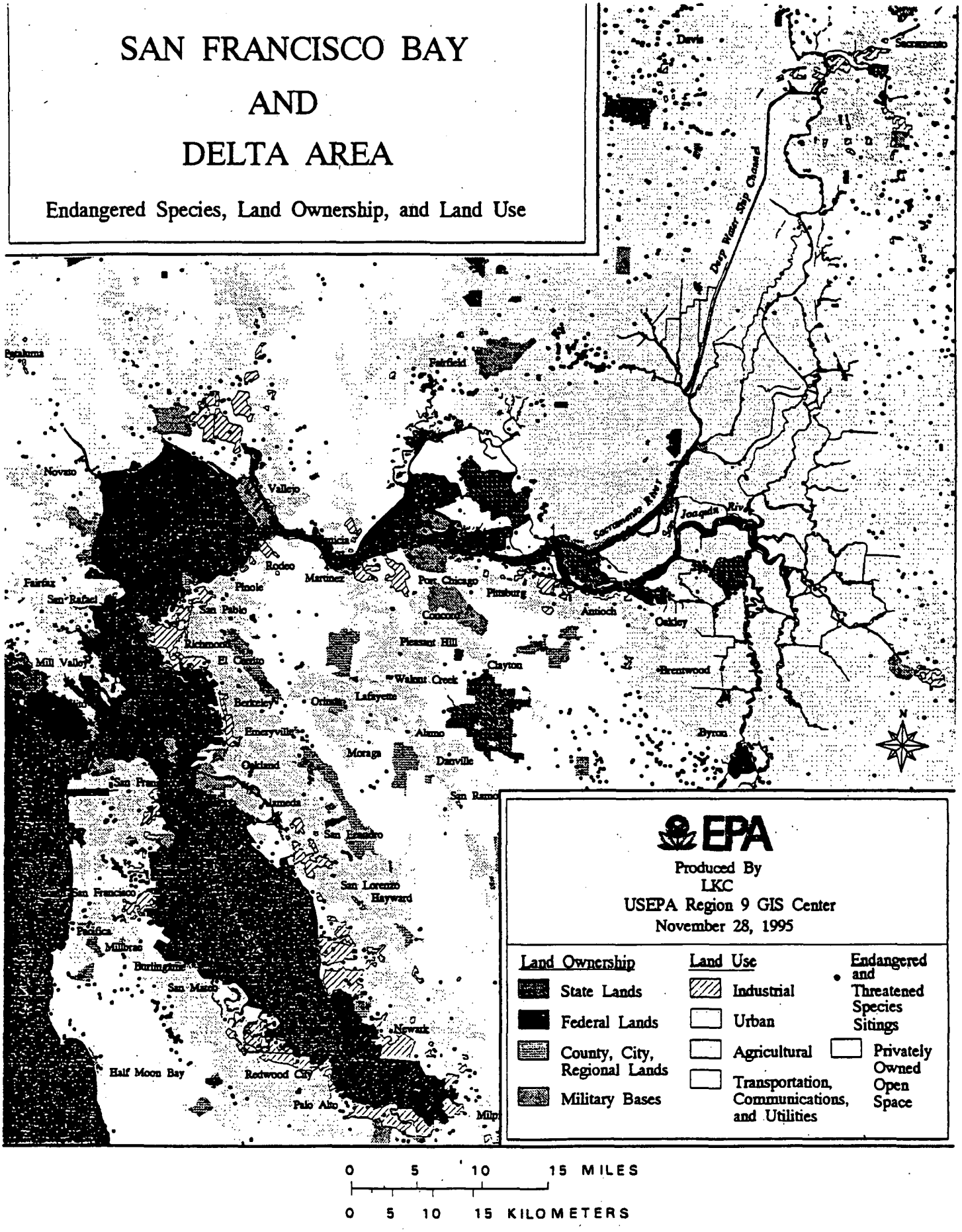

SAN FRANCISCO BAY
AND
DELTA AREA
Endangered Species, Land Ownership, and Land Use
Davis
Sacramento
Deep Water Ship Channel
Sacramento River
San Joaquin River
Petaluma
Fairfield
Novato
Vallejo
Rodeo
Martinez
Port Chicago
Pittsburg
Antioch
Oakley
Brentwood
Byron
Fairfax
San Rafael
Pinole
San Pablo
Concord
Pleasant Hill
Richmond
El Cerrito
Mill Valley
Walnut Creek
Clayton
Berkeley
Orinda
Lafayette
Emeryville
Alamo
Moraga
Danville
Oakland
San Ramon
Alameda
San Leandro
San Lorenzo
Hayward
San Francisco
Pacifica
Millbrae
Burlingame
San Mateo
Newark
Half Moon Bay
Redwood City
Palo Alto
Milpitas
N
EPA
Produced By
LKC
USEPA Region 9 GIS Center
November 28, 1995
Land Ownership
State Lands
Federal Lands
County, City, Regional Lands
Military Bases
Land Use
Industrial
Urban
Agricultural
Transportation, Communications, and Utilities
Endangered and Threatened Species Sitings
Privately Owned Open Space
0 5 10 15 MILES
0 5 10 15 KILOMETERS

Exhibit 6-3

PRINCIPAL WATERBODIES IMPAIRED BY TOXIC POLLUTION IN SAN FRANCISCO BAY BASIN (REGION 2)

Waterbody	Pollutants	303(d) Priority	Area Affected
San Francisco Bay, Central	Metals, selenium[1]	1	67,700 acres
San Francisco Bay, Lower	Metals	1	79,900 acres
San Francisco Bay, South	Metals, trace elements[1]	1	24,500 acres
Suisun Bay	Metals, arsenic	n/a	25,000 acres
Tomales Bay	Mercury	3	400 acres
Calero Reservoir	Mercury, arsenic, trace elements	4	350 acres
Guadalupe Reservoir	Nickel, trace elements	4	80 acres
Herman Lake	Mercury	5	110 acres
Alameda Creek	Trace elements	4	27 miles
Alamitos Creek	Mercury, trace elements	4	14 miles
Guadalupe River	Pesticides, other toxics	4	30 miles
Napa River	Metals	3	55 miles
Petaluma River	Metals	3	25 miles
Walker Creek	Mercury	4	25 miles
Suisun Marsh	Metals	1	57,000 acres

Sources: 303(d) list; WQA Data Base

[1] A water quality criterion of 5 μg/l is currently in effect for the San Francisco Bay/Delta; a more stringent criterion of 2 μg/l, designed to protect some species of aquatic-dependent wildlife, has been implemented in portions of the Delta's Grasslands region.

hot spots identified by this effort include Suisun Bay proper as well as several wetlands and smaller bays (Peyton Slough, Boynton Slough, Chadbourne Slough, and Honker Bay); Miller Creek (feeding the Central Bay); Castro Cove and Richmond Harbor (off of the Lower Bay); Oakland Inner Harbor; Hunters Point; Redwood Creek; Dumbarton Bridge; and the area south of Dumbarton Bridge (extreme South Bay).[16]

The information presented in Exhibit 6-3 includes data on the toxic pollutants responsible for impairing water quality in Region 2. The exhibit indicates that metals are the most common source of impairment, although selenium, arsenic, trace elements and pesticides are also problematic. Exhibit 6-4 expands upon this list, identifying specific pollutants of concern, the nature of the risks they pose to exposed organisms, and researchers' current understanding of these pollutants' impacts in San Francisco Bay. The pollutants of concern identified in Exhibit 6-4 include arsenic, cadmium, chromium, copper, lead, mercury, nickel, selenium, zinc, and PCBs. In addition, recent studies have found elevated concentrations of dieldrin, DDT, chlordane, dioxins and furans in the tissues of fish from the Bay.[17]

The sources that contribute to toxic pollution in San Francisco Bay are varied. Exhibit 6-5 summarizes estimated loadings of key toxic pollutants by point sources and other sources, including upstream sources (i.e., loadings to rivers whose waters flow to the Bay) and urban or non-urban runoff. As the exhibit indicates, upstream and nonpoint sources account for the majority of loadings for a number of toxics, including arsenic, cadmium, chromium, copper, lead, mercury, and zinc. In contrast, point sources discharge slightly more than half of the total quantity of chlorinated hydrocarbons that enter the Bay, and also account for a significant share of mercury loadings. Figures 6-7 and 6-8 note the location of the largest of these sources, as indicated by daily mean discharge volumes during the mid-1980s. As the figures illustrate, major municipal sources are distributed throughout the Bay region, with several of the largest treatment works discharging to South Bay; in contrast, major industrial dischargers - including a number of oil refineries, chemical plants, and a large steel mill - are clustered in the northern reaches of the Bay.[18]

In addition to the dimensions of the toxics problem described above, it is important to note that conservative toxic pollutants have accumulated in the sediments of the Bay. For example, sediments in Grizzly Bay have been found to contain high concentrations of arsenic, chromium, copper, nickel, and zinc, while sediments in South Bay contain the region's highest concentrations of mercury, silver, and lead.[19] Both by direct contact or accumulation through ingestion, estuarine

---

[16] State Water Resources Control Board, 1993.

[17] SFBRWQCB. 1995.

[18] USEPA, 1992.

[19] San Francisco Estuary Institute. 1993.

Exhibit 6-4

SAN FRANCISCO BAY TOXICS OF CONCERN AND THEIR EFFECTS ON ORGANISMS

Toxic	Effects on Organisms	Effects Specific to San Francisco Bay	References
Arsenic	Carcinogenic/mutagenic. Toxicity dependent on chemical form. Acutely toxic to most marine organisms.	Effect on estuary biota unknown. Probably a pollutant of less concern.	SFEP 1992; SFEI 1993; CH2M 1991b
Cadmium	Carcinogenic/mutagenic/teratogenic. Highly toxic in aquatic environments. Bioaccumulates up to 250,000 times concentration in water. Of exceptional toxicity to mammals, including humans.	A pollutant of greatest concern. Ubiquitous in Bay. Levels in biota warrant health concern and further investigation.	Herbold 1992; Flegal 1991; Ohlendorf 1988; Kopec 1994; Harvey 1992; SFEP 1992; Luoma and Phillips 1988; SFEI 1993; CH2M 1991b
Chromium	Carcinogenic/mutagenic/teratogenic. Strongly accumulates in sediments and biota. Detrimental effects in biota at levels in water of 10 ppb. Accumulates highly in sediments.	Poorly characterized in estuary. Large industrial source in Suisun Bay area. Elevated levels cause for concern and further investigation.	Herbold 1992; Harvey 1992; SFEP 1992; CH2M 1991b
Copper	Chronically toxic to marine organisms at concentrations in water of .01-10.0 ppm. Acutely toxic at concentrations in water greater than .01 ppm. Bioaccumulates in shellfish up to 30,000 times concentration in water. Highly bioavailable in the estuary.	A pollutant of greatest concern. Elevated levels in water, sediment, and biota cause for further investigation.	Herbold 1992; Flegal 1991; Kopec 1994; Harvey 1992; SFEP 1992; Luoma and Phillips 1988; SFEI 1993; CH2M 1991a; Ohlendorf 1988
Lead	Carcinogenic/teratogenic. Chronically toxic to marine organisms at concentrations in water of 0.1 ppm. Bioaccumulates readily. Highly toxic to mammals.	Given moderate toxicity and relatively even distribution, a problem only at specific sites.	Kopec 1994; Harvey 1992; SFEP 1992
Mercury	Teratogenic. Most toxic of all trace elements. Effects occur at low parts per billion level. Wide range of acute and chronic toxicities to aquatic biota. Chronic toxicity to marine organisms occurs at concentrations in water of 1 ppb. Bioaccumulates in some aquatic biota at levels 100,000 times that in water.	Possibly a pollutant of greatest concern. Given effect and high concentrations in biota, further investigation warranted.	Flegal 1991; Ohlendorf 1988; Kopec 1994; Harvey 1992; SFEP 1992; Luoma and Phillips 1988; SFEI 1993; CH2M 1991a
Nickel	Carcinogenic/mutagenic. Chronically toxic in water at levels greater than 0.1 ppm. Acutely toxic at concentrations above 1.0 ppm.	Poorly characterized in estuary. Enrichment in sediments and biota is localized.	Kopec 1994; SFEP 1992; Flegal 1991; SFEI 1993; CH2M 1991a
Selenium	Teratogenic. Toxicity depends greatly on chemical form. Toxic effects occur at concentrations of 10 ppb in freshwater, 1 ppm dry mass in sediments, and 0.3 ppm wet weight in shellfish.	A pollutant of greatest concern. Effects on biota, especially those higher in food web, and levels in water and biota warrant further investigation.	Harvey 1992

Exhibit 6-4

SAN FRANCISCO BAY TOXICS OF CONCERN AND THEIR EFFECTS ON ORGANISMS (continued)

Toxic	Effects on Organisms	Effects Specific to sn Francisco Bay	References
Zinc	Moderately toxic. Chronically toxic to marine organisms at concentrations in water of about 0.05 ppm. Acute toxicity to marine and freshwater animals occurs at concentrations in water above 0.1 ppm. Bioaccumulates in shellfish to levels 100,000 times that of water.	Toxicity and concentrations in sediment and biota indicate minor concern.	Harvey 1992; SFEP 1992; SFEI 1993; Flegal 1991; Ohlendorf 1988
PCB	Carcinogenic. More persistent than DDT. Effects occur at extremely low concentrations. Bioaccumulates at levels up to one million times that in water. May affect reproduction in birds and mammals.	Elevated levels in sediments and tissue are cause for concern. Increasing levels in black-crowned night heron linked to decreasing embryo weights and thin eggshells.	Ohlendorf 1988; Kopec 1994; Harvey 1992

Exhibit 6-5

SOURCES OF TOXIC POLLUTANT LOADINGS TO SAN FRANCISCO BAY

Pollutant	Point Sources		Other Sources	
	Raw Loadings (tons)	Percent of Total	Raw Loadings (tons)	Percent of Total
Arsenic	18.14	11.43%	140.62	88.57%
Cadmium	12.70	15.56%	68.95	84.44%
Chromium	32.66	2.57%	1,236.51	97.43%
Copper	55.34	5.51%	948.92	94.49%
Lead	41.73	7.36%	525.27	92.64%
Mercury	4.38	44.79%	5.40	55.21%
Zinc	143.34	5.18%	2,623.61	94.82%
Chlorinated Hydrocarbons	0.57	51.45%	0.53	48.55%

Notes: Point sources are defined as POTWs, industrial effluents, and power plant emissions. Other sources are defined as urban runoff, cropland runoff, forestland runoff, rangeland runoff, and upstream sources.

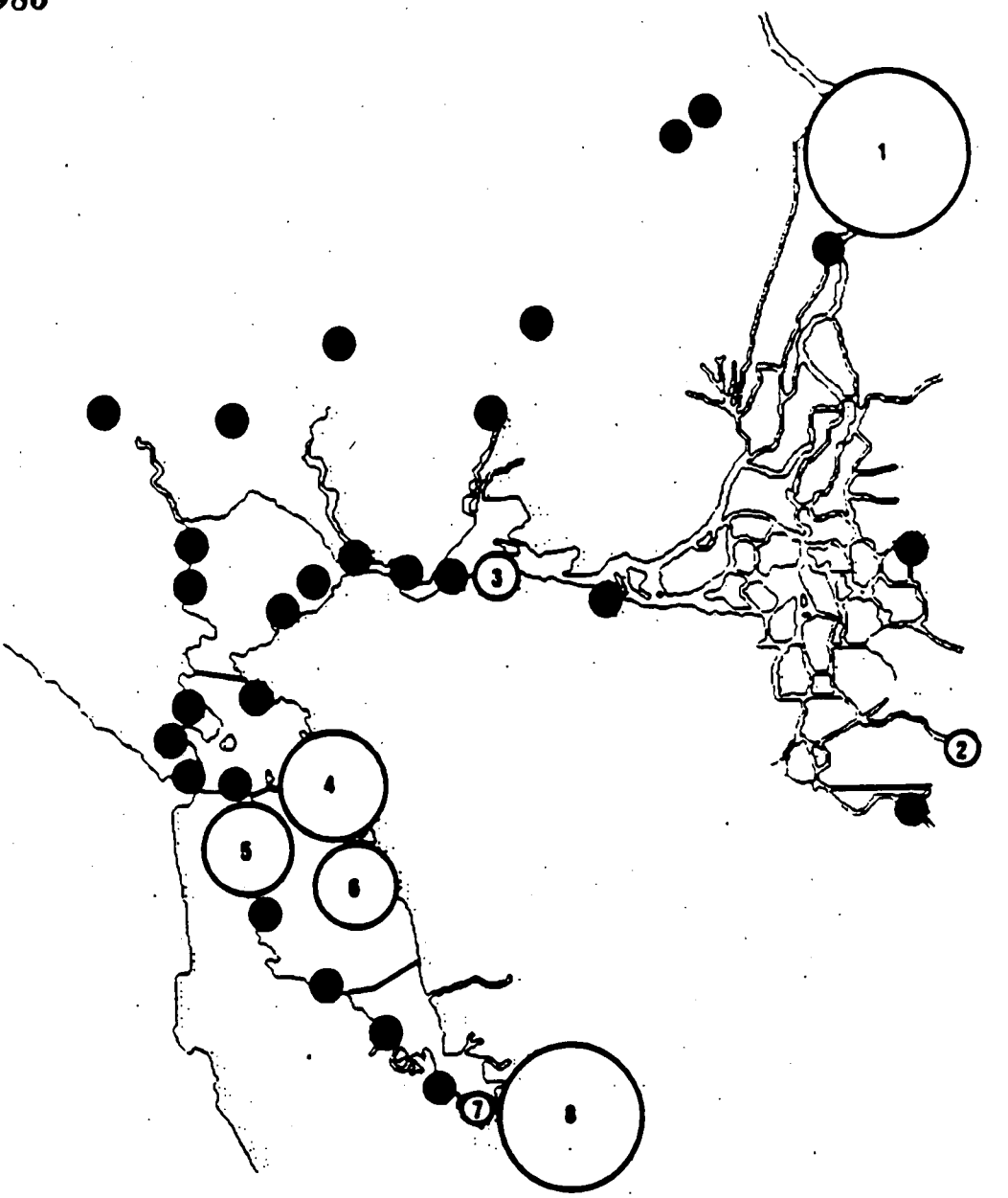
Source: NOAA, *The National Coastal Pollutant Discharge Inventory: Estimates for San Francisco Bay*, Data Summary, Ocean Assessments Division, National Oceanic and Atmospheric Administration, June 1988.

Figure 6-7

Municipal Dischargers and Mean Discharge Volumes to the Bay/Delta Estuary, 1984–1986

Eight Largest Dischargers (Discharge, Million Gallons/Day)

1. Sacramento RWTP (134)
2. Stockton STP (29)
3. Central Contra Costa SD (39)
4. East Bay MUD (87)
5. San Francisco Southeast (74)
6. East Bay Dischargers Authority (68)
7. Palo Alto WTP (28)
8. San Jose/Santa Clara WTP (118)



Note: Only discharges greater than 3 MGD are shown. Discharges up to 25 MGD are represented by dots. Discharges greater than 25 MGD are represented by circles, the areas of which are proportional to the volume of discharges.

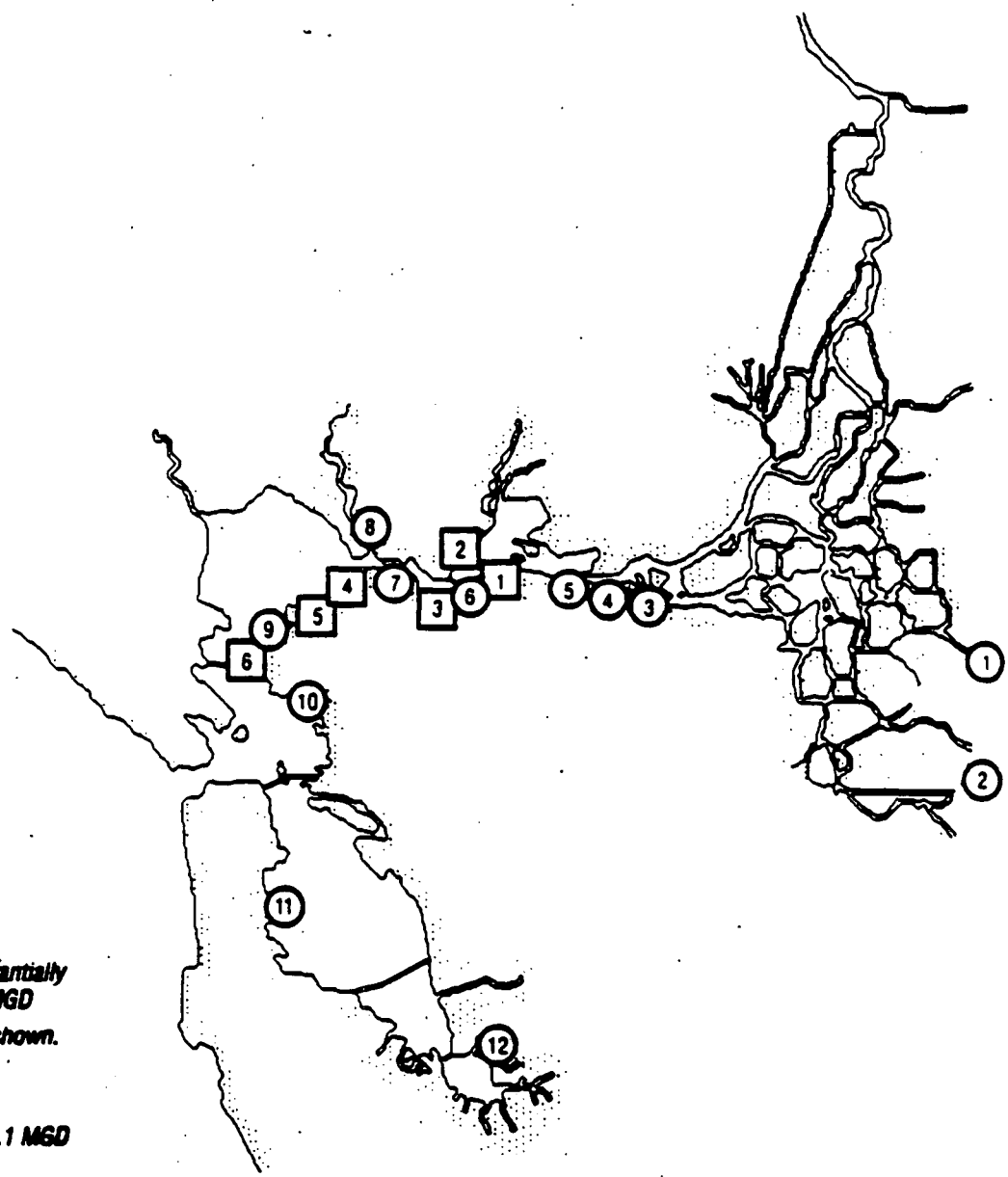
From data in Gunther et al., 1987

Figure 6-8

Industrial Facilities and Mean Discharge Volumes (Million Gallons/Day) to the Bay/Delta Estuary, 1984–1986

1 Refineries	MGD
1. Tosco	4.4
2. Exxon	2.2
3. Shell Oil	4.3
4. Union Oil	2.5
5. Pacific Refining	0.2
6. Chevron USA (a)	16.7

3 Other Industries	MGD
1. McCormick and Baxter	0.2
2. Libbey-Owens-Ford	0.2
3. USS Posco	20.0
4. Dow Chemical	0.4
5. General Chemical	1.1
6. Stauffer Chemical	0.1
7. C&H Sugar	1.0
8. Mare Island Shipyard	0.5
9. Chevron Chemical	0.2
10. Stauffer Chemical	0.1
11. San Francisco Int'l Airport	4.0
12. New United Motors	0.9



Notes

(a) Flows from Chevron USA decreased substantially after 1986. Average flow in 1990 was 7 MGD

(b) Discharges of less than 0.1 MGD are not shown.

- *Names listed are those used during the period of study.*
- *Some facilities discharging greater than 0.1 MGD did not monitor toxic pollutants.*

From data in Gunther et al., 1987

organisms may be adversely affected by contaminants in sediments or contaminant fluxes from sediments to the water column.[20] This problem is exacerbated in San Francisco Bay by the need for frequent dredging to maintain navigational access for recreational, commercial, and military vessels. In order for shipping channels to remain operative, an average of 8 million cubic yards of material must be dredged from the Bay annually. This process can lead to the re-exposure of toxic contaminants contained in buried sediments, transport of contaminated dredged material from the Bay's designated spoil disposal sites to other areas, and resuspension of contaminants in the water column, thereby increasing the bioavailability of toxic pollutants throughout the Bay.[21]

Impacts of Toxic Pollutants on Biota

Figure 6-9 illustrates the potential transport and fate of toxic pollutants introduced to an estuarine system like San Francisco Bay. The transport of a particular pollutant can be complex and difficult to predict, dependent as it is upon the pollutant's physical and chemical characteristics, as well as environmental parameters such as salinity, temperature, and direction and the direction and strength of local currents. Added to this complexity is the interaction among the estuarine organisms that comprise the food web. As illustrated in Figure 6-10, lower trophic level organisms that take in contaminants can become a toxic source for their predator counterparts. Successive bioaccumulation of toxics can occur through upper trophic levels by the consumption of contaminated prey, with the potential for impacts beyond estuary boundaries when migratory species travel from one area to another. Moreover, impacts on any one species may have implications for others, due to the complex interactions among species within an ecosystem. These interconnections must be considered to characterize fully the potential impact of toxic pollutants on the ecological resources of San Francisco Bay.

Unfortunately, the dynamic interactions among the various components of San Francisco Bay's ecosystem are far from fully characterized. Therefore, our assessment of the effects of toxic pollutants on the Bay's biota is largely anecdotal, focusing on the known or potential impacts of particular pollutants on individual species. Nonetheless, the available data indicate a number of actual or potential adverse impacts on Bay area biota due to exposure to toxic pollutants. For example:

- Exhibit 6-6 presents a hazard evaluation for waterfowl and other avian species that inhabit the Bay area, based on the concentrations of selected contaminants found in the tissues or eggs of local bird populations. The exhibit shows that mercury, selenium, DDE, and PCBs occur in

[20] Flegal, et al., 1994.

[21] USEPA, 1992.

Figure 6-9

TRANSPORT AND FATES OF POLLUTANTS IN A TYPICAL ESTUARY

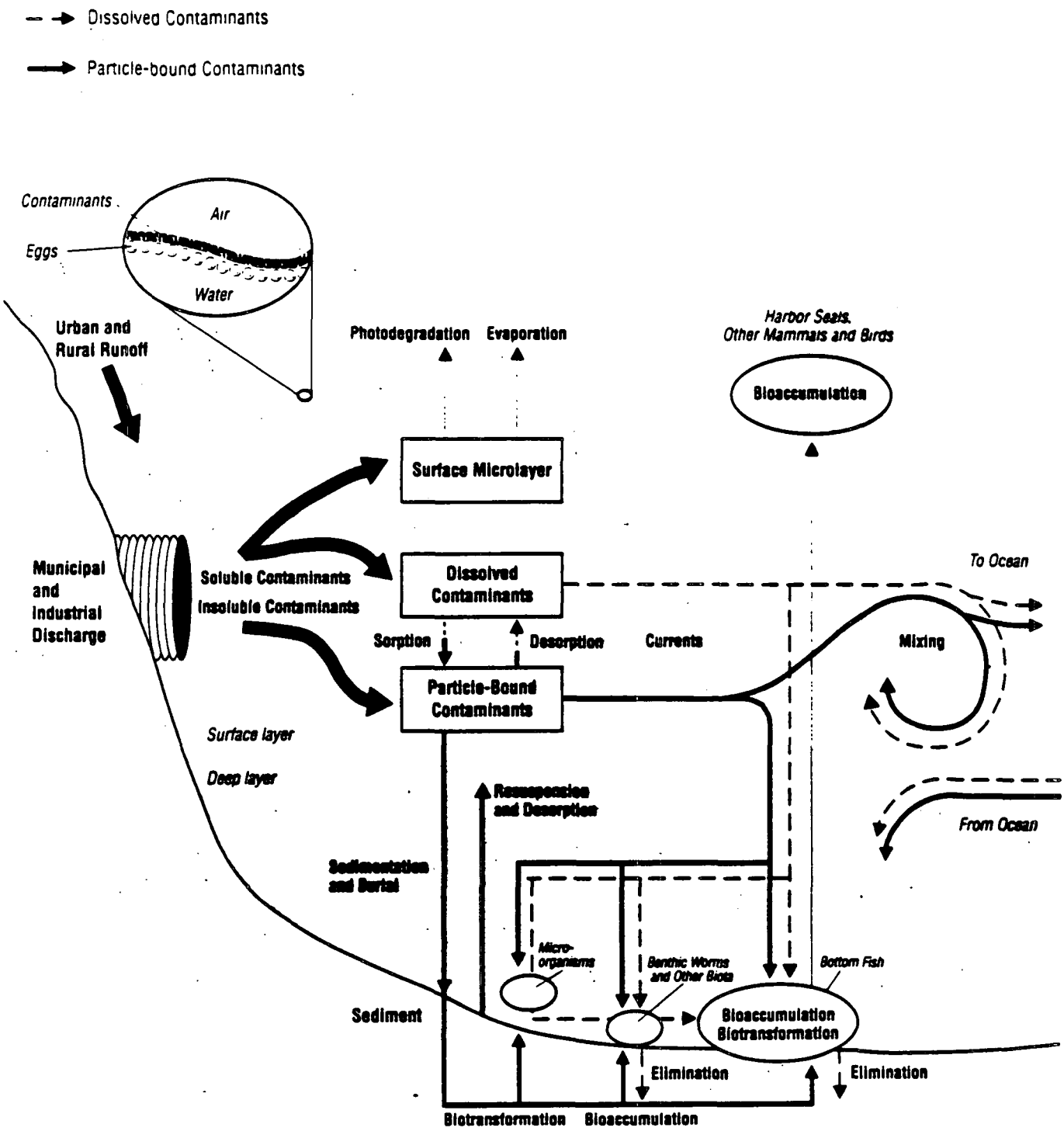


Figure 6-10

FOOD WEB OF A TYPICAL ESTUARY OPEN WATER HABITAT

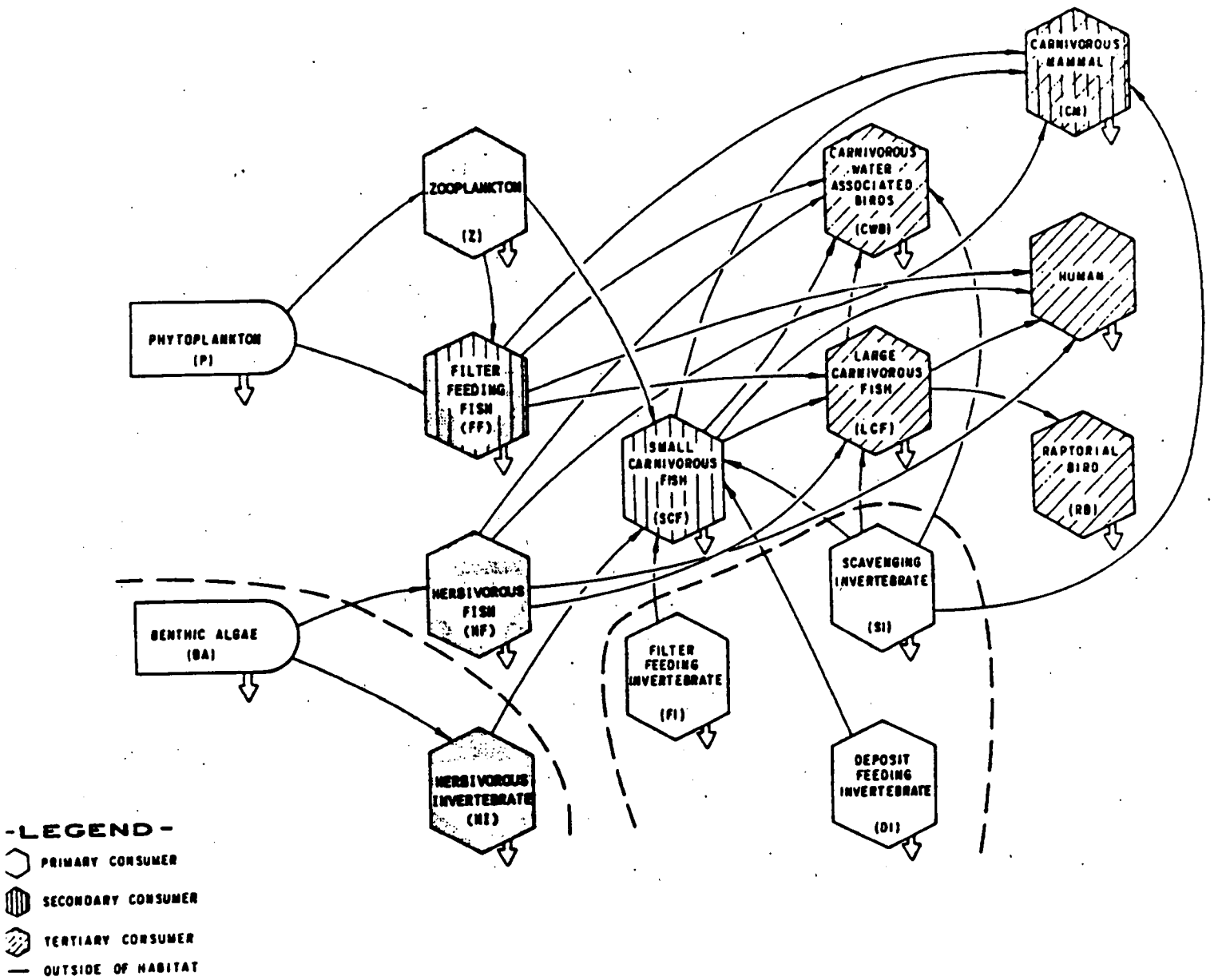


Exhibit 6-6

HAZARD EVALUATION OF ENVIRONMENTAL CONTAMINANTS IN BIRD TISSUES OR EGGS FROM SAN FRANCISCO BAY DELTA*

(From Ohlendorf and Fleming, 1988)

Species	Trace Elements									Organochlorines			References**
	Ag	Cd	Cr	Cu	Hg	Ni	Pb	Se	Zn	DDE	PCBs	Others	
Waterfowl													
Mallard	ND	ND	ND	ND	ND	ND	ND	-	ND	ND	ND	ND	1
Northern pintail	ND	ND	ND	ND	ND	ND	ND	ND	ND	-	-	-	2
Northern shoveler	ND	ND	ND	ND	ND	ND	ND	-	ND	ND	ND	ND	3
Canvasback	ND	ND	ND	ND	ND	ND	ND	+	ND	ND	ND	ND	3
Greater scaup	+	+	-	+	++	-	-	++	+	ND	ND	ND	1,3,4,5, 6,7,8,9
Lesser scaup	ND	ND	ND	ND	ND	ND	ND	++	ND	ND	ND	ND	1,3
Surf scoter	+	+	-	+	++	-	-	++	+	ND	ND	ND	1,3,4,5,6,7,9
Other species													
Double-crested cormorant	ND	ND	ND	ND	ND	ND	ND	?	ND	ND	ND	ND	1,10
American bittern	ND	ND	ND	ND	ND	ND	ND	-	ND	ND	ND	ND	3
Snowy egret	ND	ND	ND	ND	?	ND	ND	ND	ND	+	+	+	11,12
Black-crowned night heron	ND	ND	ND	ND	+	ND	ND	ND	ND	++	++	+	11,13,14
American coot	ND	ND	ND	ND	ND	ND	ND	-	ND	ND	ND	ND	1,3,15,16
Black-necked stilt	ND	ND	ND	ND	ND	ND	ND	-	ND	ND	ND	ND	1,15,16,17
American avocet	ND	ND	ND	ND	ND	ND	ND	-	ND	ND	ND	ND	1,15,17
Willet	ND	ND	ND	ND	ND	ND	ND	-	ND	ND	ND	ND	1
Caspian tern	ND	ND	ND	ND	?	ND	ND	ND	ND	+	+	+	11
Forster's tern	ND	ND	ND	ND	?	ND	ND	ND	ND	+	+	+	11

*Listed as follows, based upon field or laboratory determinations with these or other avian species:

"++" = reported concentrations in some samples are equal to or greater than those associated with adverse effects;
"+" = reported concentrations are elevated to warrant some concern although effect levels are not well known;
"-" = reported concentrations are not elevated in comparison with other areas or are below the known effect level;
"?" = relative status unknown (because comparative or effect levels are not known);
"ND" = no data available.

**References: 1 = White *et al.* (1987); 2 = Ohlendorf and Miller (1984); 3 = White *et al.* (1988); 4 = Heinz (1979); 5 = Vermeer and Peakall (1979); 6 = Di Giulio and Scanlon (1984); 7 = Ohlendorf *et al.* (1986c and in press); 8 = Gochfeld and Burger (1987); 9 = Heinz *et al.* (1987); 10 = King and Cromartie (1986); 11 = Ohlendorf *et al.* (in press); 12 = Ohlendorf *et al.* (1979); 13 = Ohlendorf *et al.* (1978); 14 = Hoffman *et al.* (1986); 15 = Ohlendorf *et al.* (1987); 16 = Presser and Ohlendorf (1987); 17 = White and Cromartie (1985).

concentrations that in some cases equal or exceed those associated with adverse effects. Contaminants such as silver, cadmium, copper, zinc, and organochlorines other than PCBs or DDE are also found in concentrations that may warrant concern. The species at risk include Greater scaup, Lesser scaup, Surf scoter, Black-crowned night heron, Caspian tern, and Forster's tern. In particular, evidence of reduced embryo weights in black-crowned night herons has been linked with PCB concentrations, and DDE concentrations in 1982-1984 were high enough to cause reproductive impairment.[22]

- There is evidence that declines in the Bay's stock of striped bass, oysters, and Dungeness crab (*Cancer magister*), as well as declines in both the winter and spring runs of chinook salmon, may be attributable in part to the deleterious effects of toxic pollutants.[23] For example, striped bass suffered a summer die-off in 1985 in the Carquinez Strait and Sacramento-San Joaquin estuary, possibly from liver dysfunction caused by exposure to hydrocarbons, chlorinated hydrocarbons, and heavy metals.[24]

- Available data suggest that reduced reproductive success and MFO[25] activity in starry flounder are related to PCB contamination.[26] PCBs are also suspected as the cause of liver abnormalities in starry flounder and a high incidence of liver lesions in white croaker from Central Bay.[27]

- Elevated concentrations of nickel, which is highly toxic to fish, invertebrates, and zooplankton, have been found in mussels in Carquinez Strait. In addition, high concentrations of chromium and silver have been detected in shellfish from Central Bay.[28]

---

[22] Aquatic Habitat Institute. 1991.

[23] AHI, p. 134.

[24] Pereira et al., 1994.

[25] Mixed-function oxidase (MFO) activity measures the enzymatic response of fish to exposure to organic contaminants.

[26] Long, et al. 1988.

[27] USEPA, 1992.

[28] USEPA, 1992.

- High concentrations of silver in South Bay are of concern because of silver's extreme toxicity to some organisms, including marine invertebrates and microorganisms. Elevated levels of silver may limit primary ecosystem productivity and reduce benthos species diversity, ultimately fostering the decline of fisheries throughout the estuary.[29]

- The U.S. Fish and Wildlife Service has found that concentrations of selenium in the tissues of certain birds and fish from the San Francisco Bay region - including the federally endangered California clapper rail, diving ducks, and white sturgeon - exceed the levels associated with potential adverse effects.[30] The San Pablo Bay and South Bay populations of the California clapper rail are particularly at risk from exposure to selenium.[31]

- Bay area populations of the California clapper rail may also be adversely affected by mercury. Recent studies indicate that mean sediment concentrations of methyl-mercury (the more toxic form of mercury) in the Bay approach calculated toxicological thresholds of about three ng/g. Maximum methyl-mercury concentrations in sediments of the North Bay (12.5 ng/g) and the South Bay (25 ng/g) exceed the toxicological thresholds by a factor of five and ten, respectively, and approach levels believed to be associated with more severe effects. [32]

- Fish consumption advisories are in effect throughout the Bay for mercury, PCBs, dioxins, and pesticides, and a waterfowl consumption advisory is in effect for selenium. While the existence of human health consumption advisories does not confirm risks to other species, it does demonstrate that these pollutants accumulate to harmful levels for at least one top consumer (humans) and implies the possibility that other top consumers (e.g., piscivorus wildlife) may also be at risk.

---

[29] Smith and Flegal, 1993.

[30] USFWS has found that ambient concentrations of selenium of 5 μg/l can result in the bioaccumulation of selenium in some species to adverse levels. Jennifer Fowler-Propst, USFWS, draft letter indicating USFWS intent to testify for the Water Quality Standards for Interstate and Intrastate Streams in New Mexico, September 27, 1993.

[31] Ohlendorf and Fleming, 1988. Selenium enriched areas near point source outfalls have also been detected by bioaccumulation of the trace element in shellfish from Suisun, San Pablo, and South Bays.

[32] Schwarzbach et al., USFWS, 1996.

Figure 6-11 provides a summary of Bay area sites exhibiting elevated concentrations of toxic pollutants in sediments or biota. As the figure illustrates, the areas of concern are numerous and widespread. Exhibit 6-7 provides additional information, summarizing expert observations regarding the adverse effects of toxic pollutants in San Francisco Bay.

Trophic Level and Food Web Impacts

Beyond the immediate impacts noted above, continued exceedence of the proposed water quality criteria could adversely alter food webs. Such impacts might include a change in primary production levels that provides less favorable prey species for upper trophic levels, and a resulting change in community composition that could culminate in an unhealthy, less diverse, less resilient ecosystem. A parallel example is illustrated in a report by Sanders and Cibik that looked at phytoplankton communities in Chesapeake Bay, which comprise the foundation of the estuarine food web. The study shows that chronic loadings of arsenic and silver have modified the competition between species, resulting in a change in species composition that has created the potential to affect preferred food organisms for resident zooplankton. "Dominant zooplankton . . . in the Chesapeake Bay exhibited dramatically decreased survival and fecundity when fed an arsenic-altered phytoplankton assemblage."[33]

Studies of highly contaminated areas of San Francisco Bay have revealed metal-induced stress among the benthos. Adverse effects are most evident in the South Bay, where silver and copper concentrations in sediments and benthic organisms are highest.[34] Although ambient toxic levels are not comprehensively and consistently measured, currently available data suggest the potential for negative impacts on San Francisco Bay's biota from chronic exposure to metals. Improved control of toxics could potentially reduce these exposures and relieve metal-induced stresses on important biotic communities.

Available information also suggests that toxic pollutants may adversely affect zooplankton populations in Suisun Bay, where the entrapment zone concentrates food particles and creates an integral feature of the food web, supporting early stages of valued fish species such as striped bass.[35] If toxics are present in such key areas, species assemblages may be altered and result in an inferior or unacceptable food source for consumers such as fish, waterfowl, and shorebirds. Such is the case

---

[33] Sanders and Cibik, 1988.

[34] Luoma and Phillips, 1988.

[35] Alpine and Cloern, 1992.

Figure 6-11

Bay Area Sites Exhibiting Elevated Pollutant Concentrations in Sediments or Biota

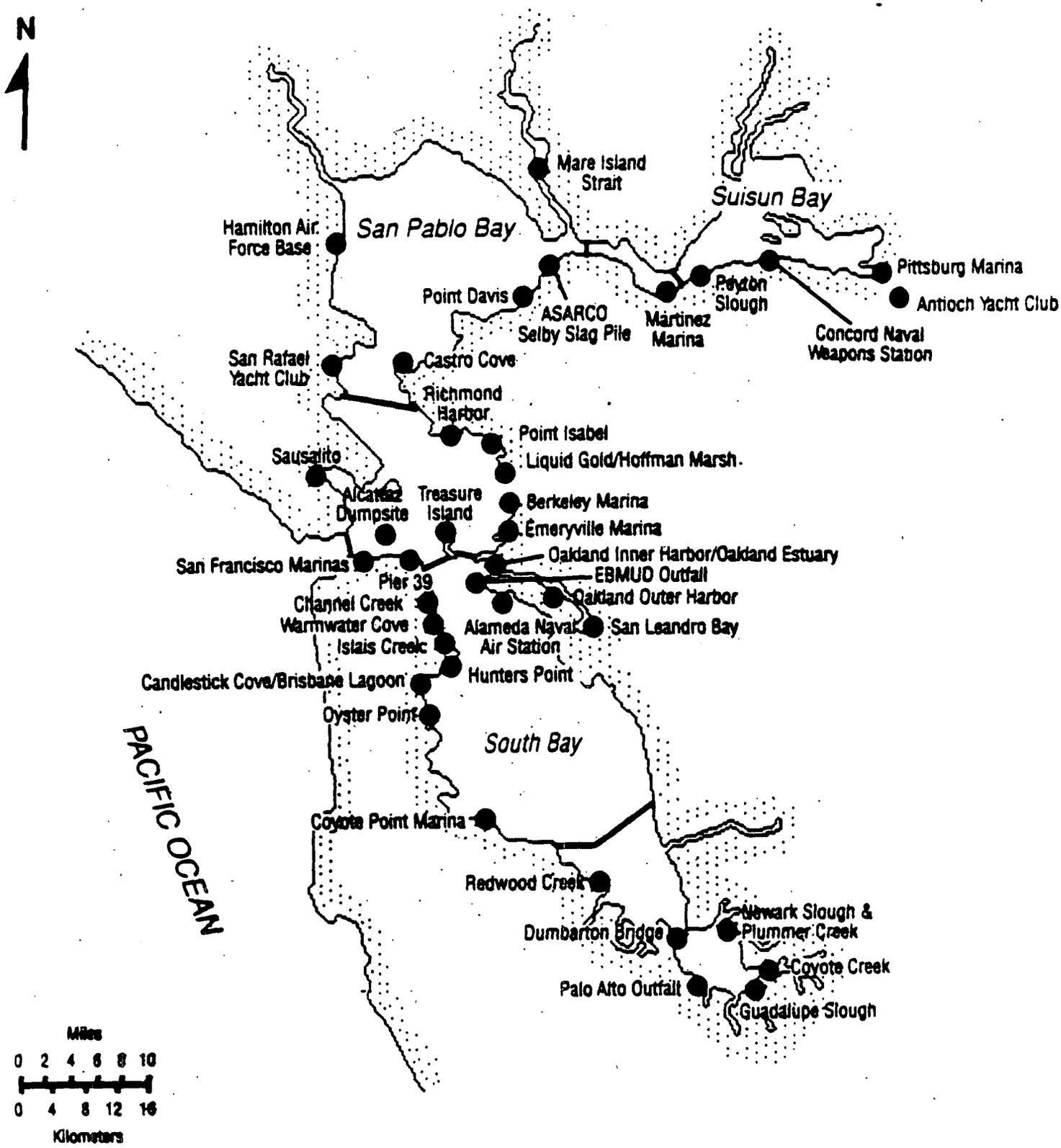


Exhibit 6-7 ANECDOTAL EXPERT OBSERVATIONS REGARDING TOXICS IN THE BAY	
Flegal et al., 1991	South Bay silver and copper concentrations of sediments and benthos highest in the Bay.
Smith and Flegal, 1993	High levels of silver contamination are of concern in South Bay since it is extremely toxic to some organisms. Metal-induced stress is found among benthos in regions of the estuary with high sediment concentrations.
Sanders and Cibik, 1988	Persistent introduction of low-level toxic concentrations may cause, "more subtle, sublethal pressure to the estuarine ecosystem, perhaps altering community structure." "The phytoplankton assemblages incorporated significant quantities of silver, in proportion to the level of silver dosing." "...chronic loading of arsenic can have serious implications to the estuary as a whole." "...natural competition between species can be modified by the presence of the low-level contaminant."
Ohlendorf and Fleming, 1988	"Mercury and cadmium concentrations in surf scoters collected in 1985...were high enough to have potential effects."
Luoma and Phillips, 1988	"Silver is strongly accumulated by invertebrates in estuaries..." "Concentrations of Cu in bivalves at several localities in South Bay and in the northern reach are as high as any reported..." Metal stress indicated in levels of biological organization in Palo Alto include: sub-cellular (M. balthica intracellular protein distribution of Cu and Ag); whole organism (M. balthica); population (M. balthica); absence of other species - whole organism bioassay; community ecology (M. balthica and A. abdita). "Stress [from metal exposure] in benthic communities is evident in extremely contaminated localities."
Herbold et al., 1992	"Industrial pollutants and urban runoff, particularly organic chemicals, heavy metals, and thermal pollution, are now the main concerns in the Bay."
Kopec et al., 1994	The environmental health of the bay is threatened by potential consequences of accumulation of toxic pollutants. "...knowledge of the biological fate and effects of toxic pollutants is inadequate for establishing discharge levels that ensure a healthy estuarine ecosystem."
Bennet et al., 1995	"...because estuaries are typically near urban and agricultural centers, cause-and-effect relationships in food webs can be obfuscated by anthropogenic interventions, including...pollution."
Harvey et al., 1992	"Environmental contaminants known to be present at concentrations that could threaten wildlife populations in San Francisco Bay Estuary include cadmium, copper, mercury, selenium, and silver." "Contaminants may adversely affect wildlife if they reduce the food base or otherwise disrupt the habitat required for the survival of wildlife." "The San Francisco Bay Estuary is a critical wintering area for diving ducks, including scaup, scoter, and canvasbacks. These and other diving ducks feed on benthic organisms, especially mussels and clams, which have been shown to contain high concentrations of ... heavy metals..." Copper and zinc concentrations in scoters were higher in the South Bay. "Contaminants have been shown to adversely affect reproduction in many species of wildlife, especially birds." Harbor seals in the Bay have been found to have elevated PCB and DDE concentrations

Exhibit 6-7

ANECDOTAL EXPERT OBSERVATIONS REGARDING TOXICS IN THE BAY (continued)

SFEP 1992	"Pollutants that enter the estuary can concentrate at high levels in animal tissues, even though they occur at low concentrations in the water and sediments." "Bioassays of estuary water, sediments, municipal and industrial effluent, urban runoff, and nonurban runoff have elicited toxic effects in many test organisms." "...concentrations of chemicals in parts of the estuary are known to equal or exceed those concentrations known to be associated with toxicity in numerous studies." "...sediments from several [sites evaluated] have elicited toxic responses including development abnormalities and high mortality in amphipods, mussels, and oysters."
Davis et al., 1991	"There is concern that many toxic pollutants being discharged into the Estuary are affecting the health of aquatic life and wildlife, therefore reducing the viability of biological communities." "...there may be additional effects, particularly effects resulting from many pollutants acting together."

with the Delta smelt, an endangered species, which subsists on a restricted diet of zooplankton (copepoda).[36] This suggests that the striped bass and other economically valuable fish in the Bay may also be affected through food chain impacts.

In addition to the impacts noted above, higher trophic level organisms in San Francisco Bay show signs of stress-related impacts from their food web connection with prey species. For example, harbor seals are tertiary predators that, as previously indicated, use San Francisco Bay as an important pupping and feeding area. They are at risk from their diet of fish, crustaceans, invertebrates, and other available prey, which pass on toxic residues in their tissues. It is believed that a reduction or change in prey species may decrease reproduction and survival of the seals; moreover, increased concentrations of toxic pollutants in prey species could accumulate in harbor seals, causing reproductive and physiological problems.[37] This possibility is supported by a recent study of harbor seals from San Francisco Bay, which found PCB residues, mercury, lead, selenium, copper, and cadmium in seal tissue samples.[38] Of particular concern is the potential for serious adverse impacts due to chronic exposure to cadmium.[39] An additional concern is exposure to lipophilic contaminants, like PCBs, which accumulate in the blubber that seals use as an energy reserve during breeding periods.[40]

Impacts on Migratory Species

As previously noted, a significant proportion of the Pacific Flyway's waterfowl and shorebird population winters in the San Francisco Bay region. The San Francisco Bay contaminants that pose the greatest risk to migratory waterfowl are cadmium, selenium and mercury, while PCBs and DDE are of greatest concern in shorebirds and black-crowned night-herons.[41] The impact of toxics on these migratory species may ultimately have far-reaching negative impacts for other ecosystems. An example of this is provided by migratory birds that overwinter in California's Imperial Valley, where they are exposed to DDT; bioaccumulation of this compound causes the birds to suffer reproductive problems in their northern breeding grounds, and may ultimately affect not only these migratory species but also their predators in northern regions.[42]

---

[36] Herbold et al., 1992.

[37] Kopec et al., 1994.

[38] Kopec et.al., 1994.

[39] Kopec and Harvey, 1995.

[40] USEPA, 1993.

[41] Ohlendorf and Fleming, 1988.

[42] Pease, 1995.

Similarly, many migratory species of fish travel through the San Francisco Bay Estuary's waters to spawn, feed, and live out various stages of their life cycles. For example, Chinook salmon, and American shad spawn in fresh water tributaries of the Bay, but live adult lives in the ocean. Longfin smelt and striped bass (see Figure 6-12) spawn in tributary streams and live in Bay or ocean waters, while Pacific herring both spawn and live their adult lives in the Bay. In contrast, English sole and starry flounder spawn outside the Bay, but migrate to the Bay during other stages of their life cycle.[43] Reduction of toxics in the Bay's waters would provide more favorable habitat that could promote higher reproductive success for these migratory fish. It would also reduce potential risks to which predators of these migratory species might otherwise be exposed.

Summary of Potential Ecological Benefits

Reducing toxic loadings to San Francisco Bay to meet the proposed water quality criteria is likely to reduce the cumulative stresses on individual organisms and populations, and to improve habitat conditions and organism health. This may in turn improve organisms' and populations' chances for success. In considering the benefits of the proposed water quality criteria, however, it is important to go beyond the potential impacts on individuals and populations. The ecosystem involves complex species assemblages that may suffer from chronic effects that do not manifest in typical measured assessment endpoints like reproduction or mortality. Often, species, populations, and communities exposed to chronic and cumulative impacts, such as those from low level toxic exposure, show very subtle signs of stress after long-term exposure. Sometimes synergistic effects from multiple stressors cause even greater adverse impacts than those predicted by looking at a single cause.

In summary, the likely ecological benefits of meeting the proposed water quality criteria for San Francisco Bay include but are not necessarily limited to the following:

- Reductions in chronic exposures to toxic pollutants should improve the reproduction, growth, general health, and survival of Estuary biota. In particular, many species that migrate through the Bay - including chinook salmon, striped bass, and waterfowl - may benefit from improved breeding habitat.

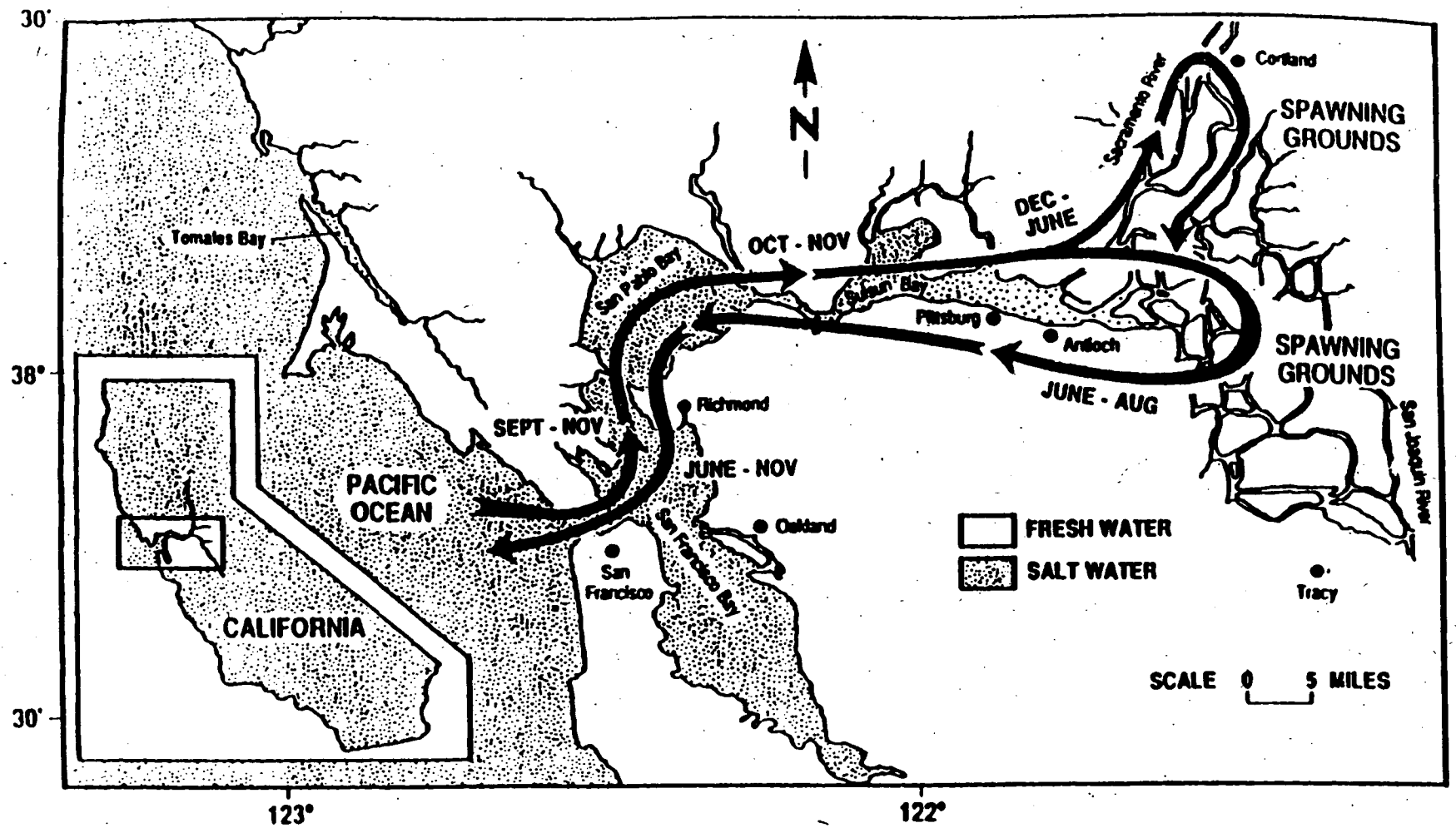
- Reductions in cumulative toxic loadings to sediments will reduce the possibility of resuspension of toxics in the water column. Filter-feeding animals such as clams and other mollusks, which take in suspended solids when feeding, are among those most likely to benefit from such reductions.

---

[43] Herbold et al., 1992.

Figure 6-12

SPAWNING AREAS AND SPAWNING MIGRATION OF STRIPED BASS
IN THE SAN FRANCISCO BAY DELTA ESTUARY



- Reduced toxic inputs to the Bay could improve habitat and enhance lower trophic-level food supplies, with the potential for contributing to improved conditions necessary for the recovery of threatened and endangered species like the California clapper rail, California brown pelican, and American peregrine falcon.

- Improved water quality conditions in the Bay may reduce the bioaccumulation of toxic pollutants in upper trophic levels. Predator species that most likely would benefit from better control of toxics include predatory fish and piscivorus birds, as well as harbor seals and other piscivorus mammals.

- Because all components of the ecosystem are linked, the improved survival, growth, productivity, and reproductive capacity of aquatic and terrestrial organisms resulting from reduced exposure to toxics should contribute to the increased stability, resilience and overall health of the Bay, and help to maintain and improve the rich biodiversity of the Estuary.

SALTON SEA

Background

The Salton Sea, California's largest inland waterbody (approximately 220,000 acres) is a saline lake located in the southeastern desert portion of California (see Figures 6-13 and 6-14 for maps of the area). The Sea was formed when a diversion set up to distribute water from the Colorado River to the Imperial Valley failed, flooding the low-lying area. The Sea is fed primarily by the New and Alamo Rivers and the Coachella Valley Storm Water Channel, each of which carry large volumes of agricultural runoff and irrigation drainage water. The Salton Sea also receives drainage water from the Mexicali Valley in Mexico. The total flow of water entering the Sea, which has no outlet, is approximately 1 million acre-feet per year.

According to the Water Quality Control Plan for the Colorado River Basin Region, the designated beneficial uses of the Salton Sea include the support of warmwater and wildlife habitat. The Sea supports a large number of artificially introduced sport fish, including orangemouth corvina, gulf croaker, sargo, and tilapia. In addition, both the Salton Sea National Wildlife Refuge and California's Imperial Wildlife Management Area are located in and around the Salton Sea. The National Refuge encompasses 45,000 acres and hosts more than 90,000 migratory waterfowl each

Figure 6-13

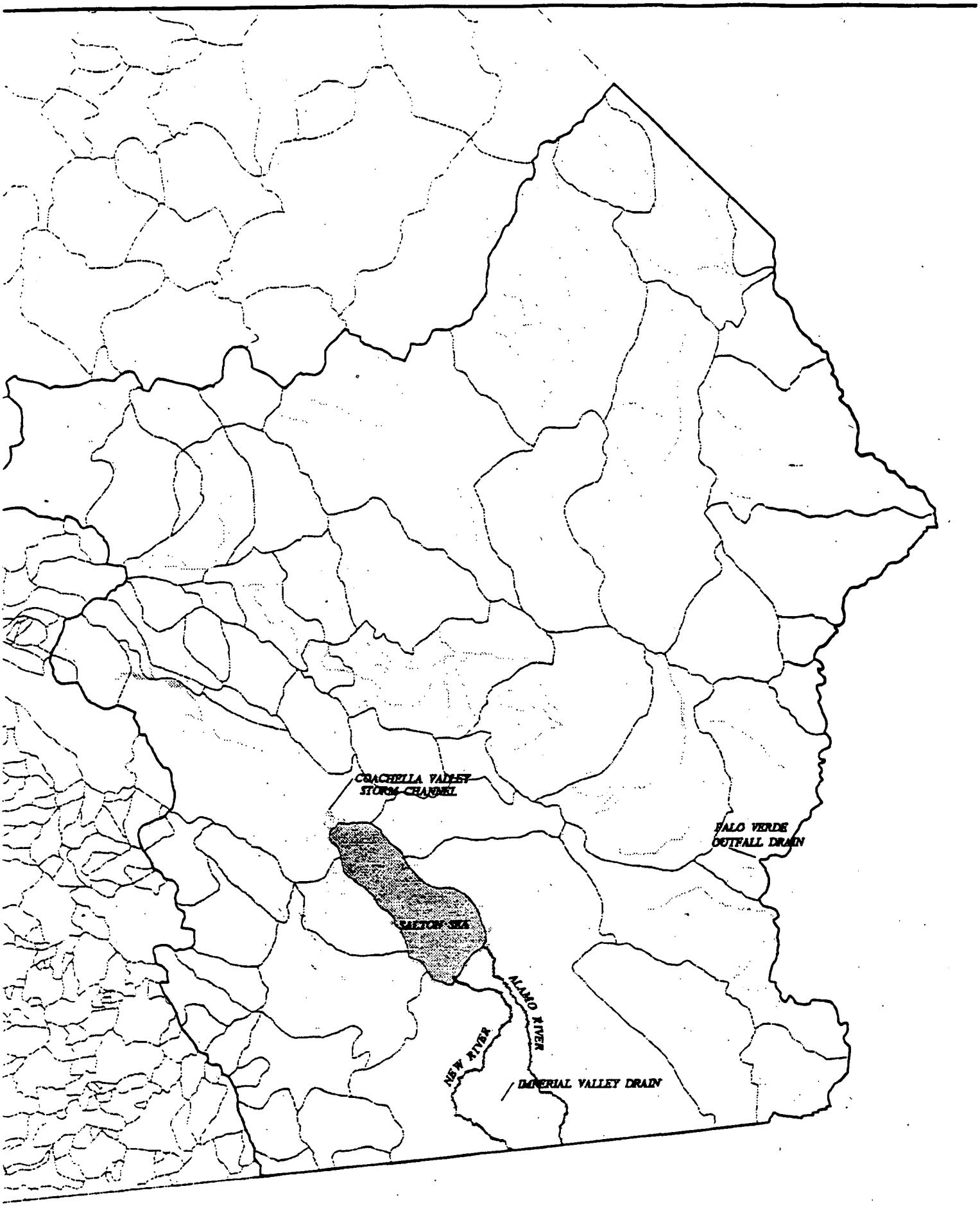
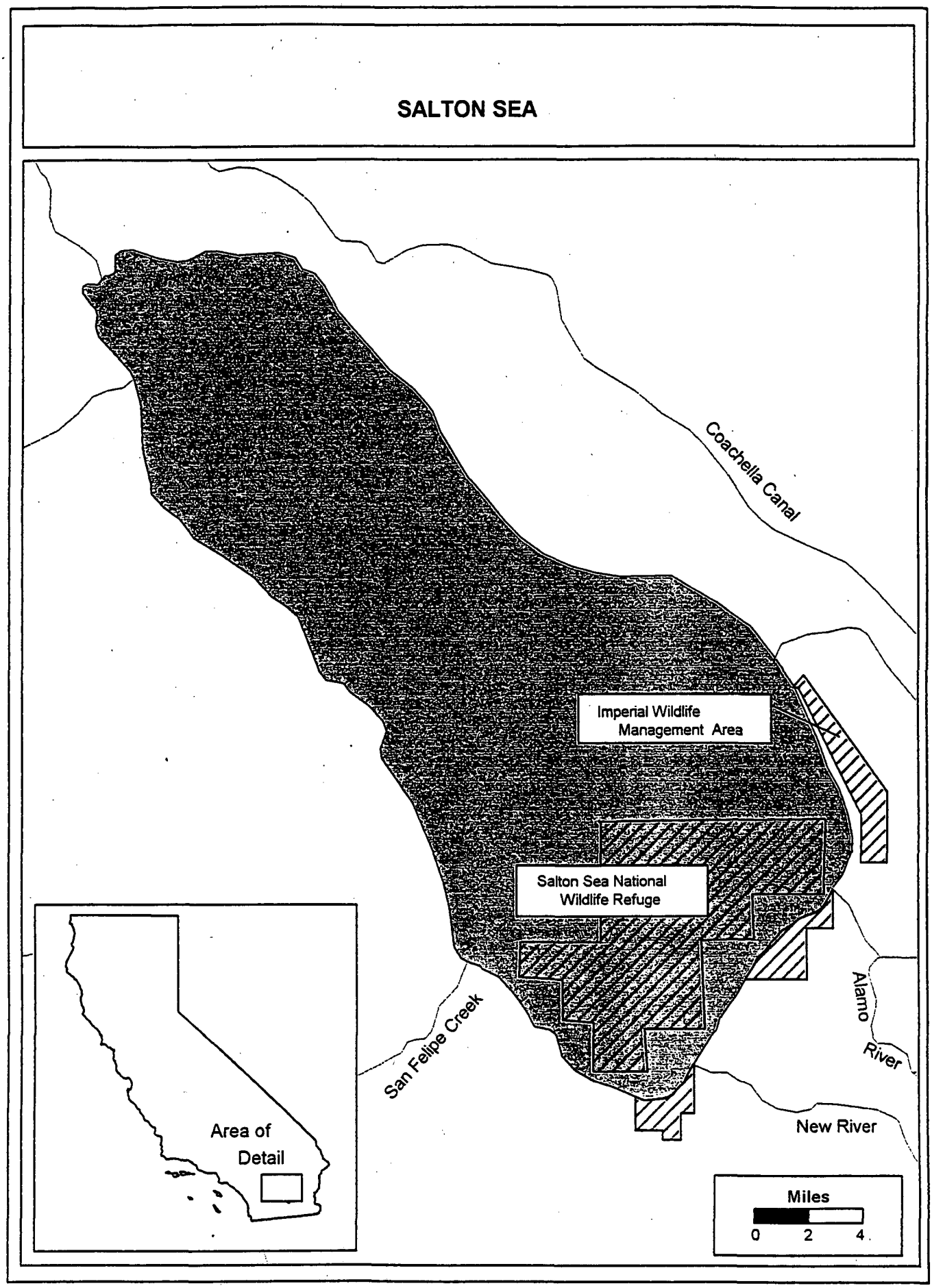

COACHELLA VALLEY
STORM CHANNEL
PALO VERDE
OUTFALL DRAIN
SALTON SEA
ALAMO RIVER
NEW RIVER
IMPERIAL VALLEY DRAIN

Figure 6-14


SALTON SEA
Coachella Canal
Imperial Wildlife Management Area
Salton Sea National Wildlife Refuge
San Felipe Creek
Alamo River
New River
Area of Detail
Miles
0 2 4

year, supporting the most diverse bird populations of any national wildlife refuge in the State.[44] The Refuge also provides essential habitat to nesting birds, including the great blue heron, cattle egret, great egret, and snowy egret. The surrounding desert is home to other birds, including piscivorus raptors, as well as to rodents, coyotes, foxes, and assorted reptiles.

As Figure 6-15 shows, several rare, threatened, or endangered species inhabit the Salton Sea area. According to the Natural Diversity Database maintained by the State, species of concern that have been identified within the confines of the Sea (or a 100 meter area surrounding it) include at least two federally-listed endangered species: the desert pupfish, which is the only fish species indigenous to the area; and the Yuma clapper rail. According to a 1993 U.S. Geological Survey (USGS) report, about one-third of the world's population of Yuma clapper rails inhabit wetlands near the Salton Sea. Other federally-listed endangered species found in the area include the peregrine falcon and bald eagle. In addition, as many as 5,000 brown pelicans, another federally-listed endangered species, occasionally spend their summers on the Salton Sea.[45]

Nature of Toxics Impairment

California's WQA database indicates that elevated loadings of trace elements, including selenium, impair water quality in the Salton Sea. Other potential toxics problems in the Salton Sea area include elevated concentrations of pesticides in the Alamo River, New River, and Coachella Valley Storm Channel, and slightly elevated concentrations of chromium and cadmium in irrigation drainwater. Elevated concentrations of mercury have also been detected in the Salton Sea area.[46]

The United States Geological Survey has conducted many studies on the quality of the water column and sediments in the Salton Sea. Sampled concentrations of selenium, the key trace element of concern, are shown in Figure 6-16. The exhibit compares these concentrations to EPA's proposed water quality criteria of 5 micrograms per liter for chronic exposure for the protection of aquatic organisms. As the exhibit indicates, 10 of the 12 samples exceed the chronic water quality criterion and six exceed higher levels associated with more acute effects, with the highest reported concentrations associated with tile drain outfalls. Other pollutants of concern identified in sediment studies include DDT metabolites (DDE and DDD), which have been detected in Alamo and New River sediments, and other organochlorine pesticides, including chlordane and toxaphene.[47]

---

[44] U.S. Geological Survey, 1990.

[45] U.S. Geological Survey, 1993.

[46] U.S. Geological Survey, 1993.

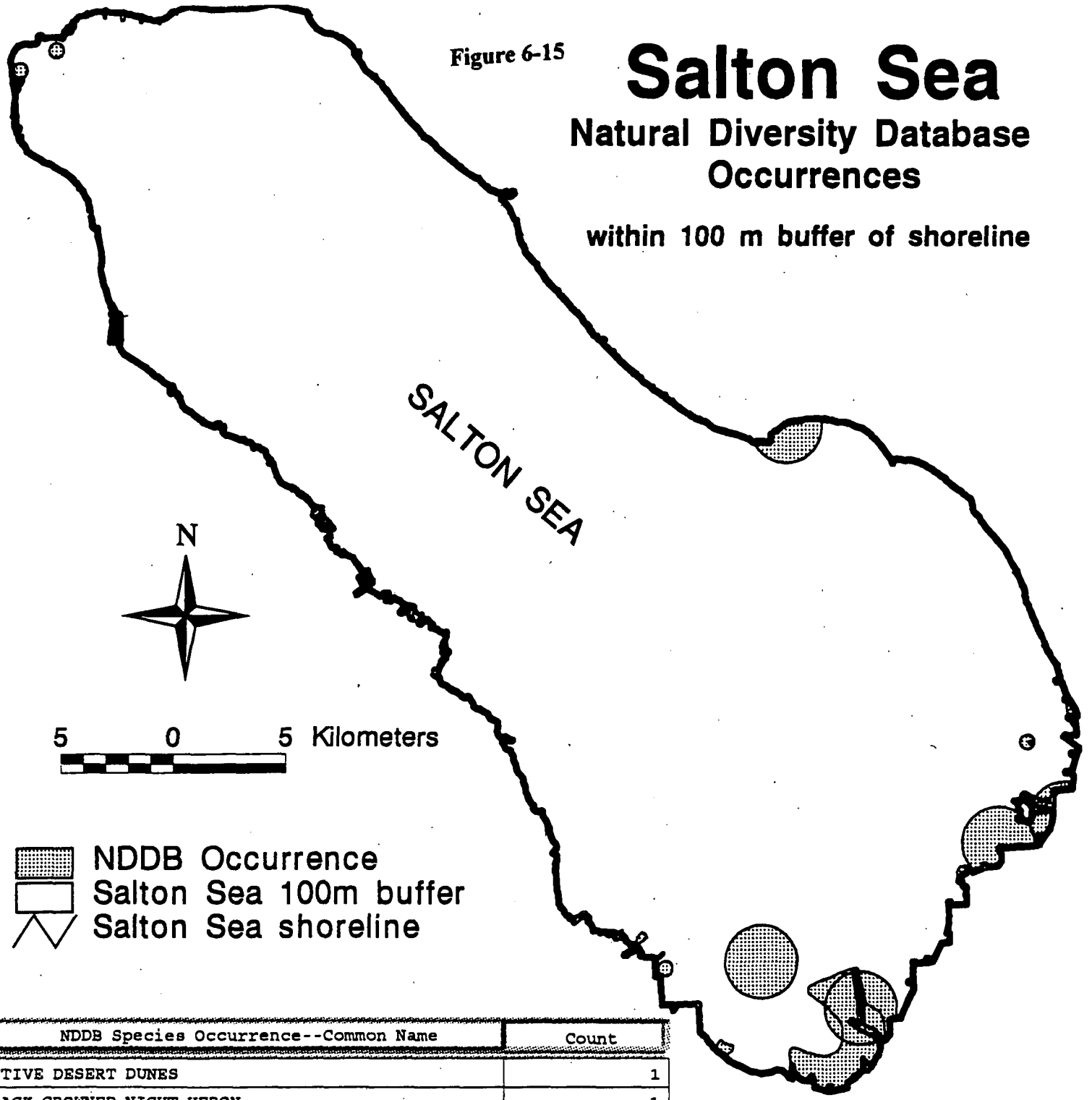
[47] U..S. Geological Survey, 1990.

Figure 6-15

Salton Sea

Natural Diversity Database Occurrences

within 100 m buffer of shoreline



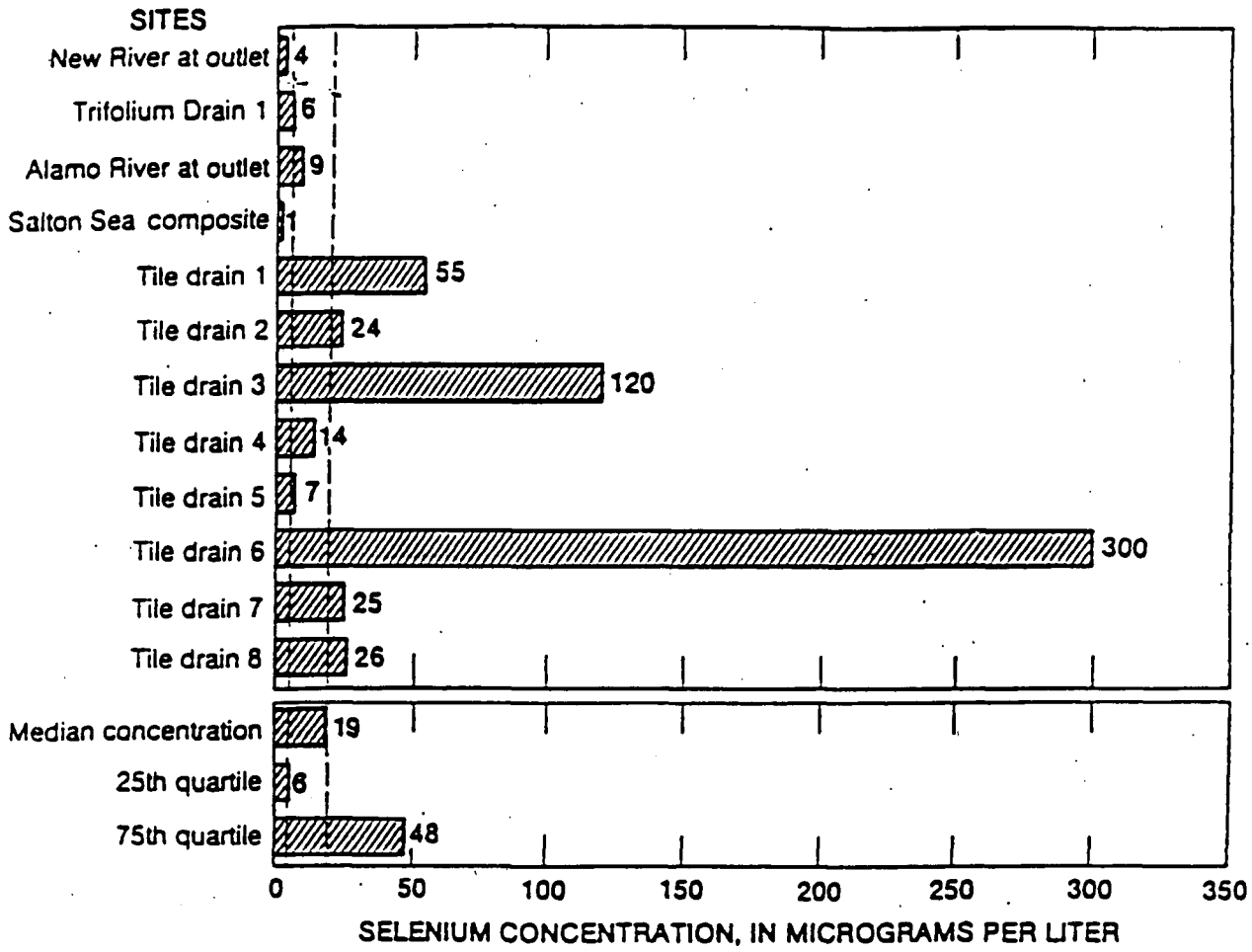
NDDB Species Occurrence--Common Name	Count
ACTIVE DESERT DUNES	1
BLACK CROWNED NIGHT HERON	1
BLACK SKIMMER	2
BLACK-TAILED GNATCATCHER	1
CRISSAL THRASHER	1
DESERT PUPFISH	43
GREAT BLUE HERON	1
GREAT EGRET	1
GULL BILLED TERN	4
LE CONTES THRASHER	1
SNOWY EGRET	1
STABILIZED AND PARTIALLY STABILIZED DESERT DUNES	1
YELLOW BREASTED CHAT	2
YELLOW WARBLER	1
YUMA CLAPPER RAIL	5

Map produced by California Rivers Assessment

Data provided by Natural Heritage Division, CA DFG

Figure 6-16

CONCENTRATIONS OF SELENIUM IN WATER SAMPLES FROM THE SALTON SEA AREA, 1986



Source: Adapted from *Reconnaissance Investigation of Water Quality, Bottom Sediment, and Biota Associated with Irrigation Drainage in the Salton Sea Area, California, 1986-1987,* U.S. Geological Survey, Water Resources Investigations Report 89-4102, 1990, p. 29.

Effects on Biota

Selenium is the contaminant of greatest concern in the Salton Sea area. Once it enters the sediments of the Salton Sea, selenium is taken up by sediment feeding organisms and enters the food web, where it bioaccumulates and biomagnifies to toxic levels. The increased concentration of selenium in plant and animal material can then pose substantial risks to the health and survival of fish and piscivorus birds. Exhibit 6-8 summarizes several of the adverse effects that selenium can have on fish and wildlife at concentrations observed in the Salton Sea. Adverse impacts include reduced survival, inhibited reproduction, reduced growth, behavioral modifications, gross deformities, immuno-suppression, and death.

Exhibit 6-8

SUBLETHAL EFFECTS TO FISH AND WILDLIFE RESOURCES FROM IRRIGATION DRAINWATER CONSTITUENTS (Primarily Selenium)

Category	Observed Effect
Reproduction	Reduced fertility Increased mutagenesis and teratogenesis Reduced egg production (number/size/rate) Eggshell thinning Reduced hatching success Reduced oogenesis/spermatogenesis
Growth/Physical	Reduced length, weight, and height; gross deformities
Internal Structure	Altered organs (heart, liver, bones) Altered cells (chromosomes) Intestinal lesions
Behavior	Abnormal mating, nesting Altered migration Reduced predator avoidance Reduced bodily maintenance (feeding, bathing)
Physiology	Altered osmoregulation Altered immune response
Biochemistry	Altered concentrations/ratios of: acetocholinase, adenosine triphosphatase, glutathione peroxidase, and other enzymes

Source: *An Overview of Irrigation Drainwater Techniques, Impacts on Fish and Wildlife Resources, and Management Options*, U.S. Fish and Wildlife Service, May 1992.

Excessive levels of selenium found in some fish in the Salton Sea area are believed to be responsible for observed declines in fish populations. Evidence has shown a significant decrease in the reproductive capacity of two forage fish, bairdiella and sargo. In addition, deformities such as retarded cephalic development have been observed in some fish; the selenium concentration in the species may be at least partially responsible for the observed deformities.[48]

Selenium's impact on birds in the Salton Sea area has been even more pronounced. A 1993 U.S. Fish and Wildlife Service assessment identifies 92 avian species in the area that may suffer adverse effects from exposure to elevated concentrations of pollutants originating from irrigation drainage. In particular, the levels of dietary selenium faced by northern shovelers, black-necked stilts, and eared grebes are high enough to pose a risk of embryotoxicity. Moreover, concentrations of selenium in the liver of double-breasted cormorants in the area averaged approximately 25 micrograms per gram of body weight from 1986 through 1990, with a maximum detected concentration of 42 micrograms per gram. These levels approach or exceed the 30 micrograms per gram threshold for risk of reproductive impairment. Consistent with these conditions, the number of active double-crested cormorant nests observed in the Salton Sea area declined from 63 in 1987 to zero in 1991.[49]

California's Toxic Substances Monitoring Program has also identified high concentrations of pesticides as a potential ecological threat in the Salton Sea area. For example, the area has the State's highest detection rate for endosulfan -- double the State average -- indicating the likelihood that aquatic organisms are chronically exposed to elevated concentrations of this pesticide. The bioaccumulation of this compound has resulted in the detection of concentrations as high as 2,050 parts per billion in fish samples collected near the Salton Sea National Wildlife Refuge. [50] Such high concentrations of endosulfan pose reproductive and other risks to piscivorus birds.

Exhibit 6-9 summarizes the findings of a USGS analysis of the impact of toxics on avian species in the Salton Sea area. As the exhibit indicates, current exposure to selenium poses a threat to 83 percent of both resident and migratory bird species; it also poses a risk to three of four Federally endangered species. Similarly, exposure to DDE, a metabolite of DDT, poses a risk to 81 percent of the area's resident bird species and 62 percent of its migratory species, including three of the area's four Federally endangered bird species. These figures suggest significant potential for ecological harm associated with exposure to the toxic substances to be regulated under the proposed water quality criteria.

---

[48] U.S. Geological Survey, 1993.

[49] U.S. Geological Survey, 1993.

[50] Pease, 1995.

Exhibit 6-9

NUMBER OF BIRD SPECIES IN THE SALTON SEA AREA ACTUALLY OR POTENTIALLY INJURED BY EXPOSURE TO SELENIUM OR DDE*

Category	Total Species	Selenium	DDE*
Resident	42	35 (83%)	34 (81%)
Migratory	82	68 (83%)	51 (62%)
Federally endangered	4	3 (75%)	4 (100%)

Source: *Detailed Study of Water Quality, Bottom Sediment, and Biota Associated with Irrigation Drainage in the Salton Sea Area, California, 1988-1990.* U.S. Geological Survey, 1993.

* DDE is a metabolite of DDT.

Potential Ecological Benefits

As described above, selenium and pesticides have accumulated in the sediment and biota of the Salton Sea area in concentrations that have deleterious impacts on fish and wildlife populations. This affected population includes the brown pelican, peregrine falcon, bald eagle, Yuma clapper rail, and desert pupfish, all of which are listed by the U.S. Fish and Wildlife Service as endangered species.

Reducing concentrations of selenium and pesticides to meet aquatic criteria levels is likely to contribute to the improved health, survival, and reproduction of fish and birds in the Salton Sea. The proposed selenium criteria may not yield full benefits for some aquatic-dependent wildlife species and populations.[51] Moreover, reducing current loadings of these pollutants is unlikely to yield immediate benefits, due to the already elevated concentration of the pollutants in the sediments and food web. Over time, however, reduced concentrations of toxic contaminants to the Sea should contribute to the maintenance and restoration of healthy populations of wildlife and could significantly contribute to the recovery of certain endangered species.

[51] The U.S. Fish and Wildlife Service has recommended a selenium criterion of 2 μg/liter to protect some aquatic-dependent wildlife.

REFERENCES

Alpine, A. E. and J. E. Cloern. 1992. "Trophic Interactions and Direct Physical Effects Control Phytoplankton Biomass and Production in an Estuary," in *Limnology and Oceanography* 37(5): 946-955.

Aquatic Habitat Institute. 1991. *San Francisco Estuary Project: Status and Trends Report on Pollutants in the San Francisco Estuary. Final Draft*. Richmond, CA, (March).

Bennet, et al. 1995. "Larval Striped Bass Condition in a Drought-Stricken Estuary: Evaluating Pelagic Food-Web Limitation," in *Ecological Applications*, Vol. 5, No. 3.

California Regional Water Quality Control Board. 1986. *Water Quality Control Plan, San Francisco Bay Basin Region (2)*, (December).

California Report on Impaired Surface Waters, Prepared as Required in Clean Water Act Section 303(d), May 1994.

Casarett & Doull's Toxicology: The Basic Science of Toxics. 3rd Edition. New York. Macmillan. 1986.

CH2M Hill. 1991. *Results of Ambient Toxicity Characterization Testing in the Vicinity of the San Jose/Santa Clara Water Pollution Control Plant*, prepared by Larry Walker Associates and Kinetic Laboratories, Inc., for the City of San Jose, (July).

CH2M, 1991. *Bioaccumulation Monitoring of Trace Elements in South San Francisco Bay Using Transplanted Marine Mussels (*Mytilus californianus*)*, prepared by Larry Walker Associates and Kinetic Laboratories, Inc., for the City of San Jose, (July).

Flegal, A. R. et al. 1991. "Dissolved Trace Element Cycles in the San Francisco Bay Estuary," in *Marine Chemistry* 36(1991):329-363.

Flegal, A. R. et al. 1994. *San Francisco Estuary Pilot Regional Monitoring Program: Sediment Studies. Final Report, Prepared for the San Francisco Bay Regional Water Quality Control Board*, State Water Resources Control Board. San Francisco, CA.

Harvey, T.E., K.J. Miller, R.L. Hothem, M.J. Rauzon, G.W. Page and R.A. Keck. 1992. *Status and Trends Report on Wildlife of the San Francisco Estuary*, prepared by the U.S. Fish & Wildlife Service for the San Francisco Estuary Project, U.S. Environmental Protection Agency. San Francisco, CA.

REFERENCES

Harvey, J.T., and M.L. Torok. 1994. "Movements, Dive Behaviors, and Food Habits of Harbor Seals (*Phoca vitulina Richardsi)* in San Francisco Bay, California," *Toxic Pollutants, Health Indices, and Population Dynamics of Harbor Seals in San Francisco Bay, 1982-1992*, A Final Report By A.D. Kopec and J.T. Harvey, (October).

Herbold, B., A. D. Jassby, and P. B. Moyle. 1992. *Status and Trends Report on Aquatic Resources in the San Francisco Estuary*, prepared by the San Francisco Estuary Project. Oakland, CA.

Karras, G. 1992. "Clean Safe Jobs: the Benefits of Toxic Pollution Prevention and Industrial Efficiency to the Communities of South San Francisco Bay," a preliminary report prepared for Citizens for a Better Environment. San Francisco, CA. 25 pp.

Kirshner, D. and D. Moore. 1988. "The Effect of San Francisco Bay Water Quality on Adjacent Property Values," *Journal of Environmental Management* 27(1989):263-274.

Kockelman, W.J., T.J. Conomos and A.E. Leviton. 1982. *San Francisco Bay: Use and Protection*, Sixty-first Annual Meeting of the Pacific Division/American Association for the Advancement of Science. San Francisco, CA. 310 pp.

Kopec, A. D., J. T. Harvey, and M. L. Torok. 1994. *Toxic Pollutants, Health Indices, and Population Dynamics of Harbor Seals in San Francisco Bay*, a preliminary report submitted to the San Francisco Estuary Project. Moss Landing Marine Laboratories. Moss Landing, CA.

Long, E.R., D. MacDonald, B.B. Matta, K. VanNess, M. Buchman, and H. Harris. 1988. *Status and Trends in Concentrations of Contaminants and Measures of Biological Stress in San Francisco Bay*, NOAA Technical Memorandum NOS OMA 41. Seattle, WA, (May).

Luoma, S. N. and D. J. H. Phillips. 1988. "Distribution, Variability, and Impacts of Trace Elements in San Francisco Bay," *Marine Pollution Bulletin* 19(9):413-425.

Moore, S. 1995. "Moseley Tract Salt Marsh Restoration Proposal: Mitigation Credit Recommendation for San Jose/Santa Clara Water Pollution Control Plant," Staff Report, California Regional Water Quality Control Board, San Francisco Bay Region, San Francisco, CA, (August).

Ohlendorf, H.M and W.J. Fleming. 1988. "Birds and Environmental Contaminants in San Francisco and Chesapeake Bays," *Marine Pollution Bulletin* 19(9):487-495.

Pease, William, Pesticide Impacts on California Ecosystems, 1995 (Draft) California Policy Seminar, Berkeley, California.

REFERENCES

Pereira, W.E., F.D. Hostettler, J.R. Cashman, and R.S. Nishioka. 1994. "Occurrence and Distribution of Organochlorine Compounds in Sediment and Livers of Striped Bass (*Morone saxatilis*) from the San Francisco Bay-Delta Estuary," *Marine Pollution Bulletin*. Vol. 28, No. 7.

Pianka, E.R. 1983. *Evolutionary Ecology*. Third Edition. Harper & Row, Publishers, Inc. New York, NY. 416 pp.

Rickleffs, R. E. 1982. *Ecology*. Second edition. Chiron Press, Inc. New York, NY. 966 pp.

San Francisco Estuary Institute. 1993. *Annual Report: San Francisco Estuary Regional Monitoring Program for Trace Substances*. San Francisco, CA.

San Francisco Estuary Project. December 1990. "San Francisco Estuary Project Fact Sheet," San Francisco, CA.

San Francisco Bay Regional Water Quality Control Board. 1995. *Contaminant Levels in Fish Tissue from San Francisco Bay: Final Report*, (June).

Sanders, J. G. and S. J. Cibik. 1988. "Response of Chesapeake Bay Phytoplankton Communities to Low Levels of Toxic Substances," *Marine Pollution Bulletin* 19(9):439-444.

Setzler-Hamilton, E.M., J.A. Whipple, and B. Macfarlane. 1988. "Striped Bass Populations in Chesapeake and San Francisco Bays: Two Environmentally Impacted Estuaries," *Marine Pollution Bulletin*, Vol. 19, No. 9.

Skorupa, J. 1991. Testimony of Dr. Joseph Skorupa regarding selenium risk thresholds, with special reference to San Francisco Bay. Presented before the California RWQCB, San Francisco Bay Region, January 16, 1991.

Smith, G. J. and A. R. Flegal. 1993. "Silver in San Francisco Bay Estuarine Waters," *Estuaries* 16(3A):547-558.

State of California. 1995. *California Hunting Regulations for Resident and Migratory Game Birds*.

State Water Resources Control Board. 1993. *Bay Protection and Toxic Cleanup Program: Staff Report*, California Regional Water Quality Control Board, San Francisco Bay Region, (November).

REFERENCES

U.S. Department of Commerce. 1987. *San Francisco Bay: Issues, Resources, Status and Management*, National Oceanic and Atmospheric Administration, NOAA Estuarine Programs Office, (October).

USEPA. 1992. *State of the Estuary: A Report on the Conditions and Problems in the San Francisco Bay/Sacramento-San Joaquin Delta Estuary*, Region 9 (June).

USEPA. 1993. *Wildlife Exposure Factors Handbook.* Washington, DC.

USEPA. 1994. *Regulatory Impact Assessment of the Final Water Quality Standards for the San Francisco Bay/Delta and Critical Habitat Requirements for the Delta Smelt.* December 15, 1994. San Francisco, CA. With technical assistance from Jones & Stokes Associates, Inc. Sacramento, CA (JSA 94-130).

USFWS. 1993. Draft letter of USFWS intent to testify for the Water Quality Standards for Interstate and Intrastate Streams in New Mexico, September 27, 1993. Jennifer Fowler-Propst, author.

U.S. Fish and Wildlife Service, 1992. Status and Trends Report on Wildlife of the San Francisco Estuary, January.

Western Hemisphere Shorebird Reserve Network, 1996. WWW Homepage. Http://www.quickweb.com/wetnet/imagemap.html.

REFERENCES FOR CHAPTER 6 FIGURES

Figure 6-1: U.S. EPA, 1992.

Figure 6-2: Kopec, 1994.

Figure 6-3: USFWS, 1992.

Figure 6-4: U.S. EPA, 1992.

Figure 6-5: Western Hemisphere Shorebird Reserve Network, 1996.

Figure 6-6: U.S. EPA Region IX, GIS Center, 1995.

Figure 6-7: U.S. EPA, 1992.

Figure 6-8: U.S. EPA, 1992.

Figure 6-9: U.S. EPA, 1992.

Figure 6-10: U.S. EPA, 1992.

Figure 6-11: U.S. EPA, 1992.

Figure 6-12: Setzler-Hamilton, 1988.

Figure 6-13: U.S. EPA Region IX, GIS Center, 1995.

Figure 6-14: U.S. EPA Region IX, GIS Center, 1995.

Figure 6-15: U.S. EPA Region IX, GIS Center, 1995.

REFERENCES FOR EXHIBIT 6-6

Di Giulio, R.T. and Scanlon, P.F. 1984. Heavy metals in tissues of waterfowl from the Chesapeake Bay, USA. *Environ. Pollut. (Ser. A)* 35: 29-48.

Heinz, G.H. 1979. Methylmercury: reproductive and behavioral effects on three generations of mallard ducks. *J. Wildl. Manage.* 43: 394-401.

Heinz, G.H., Hoffman, D.J., Krynitsky, A.J., and Weller, D.M.G. 1987. Reproduction in mallards fed selenium. *Environ. Toxicol. Chem.* 6: 423-433.

Hoffman, D.J., Rattner, B.A., Bunck, C.M., Krynitsky, A., Ohlendorf, H.M., and Lowe R.W. 1986. Association between PCBs and lower embryonic weight in black-crowned night heron in San Francisco Bay. *J. Toxicol. Environ. Health.* 19: 383-391.

Gochfeld, M. and Burger, J. 1987. Heavy metal concentrations in the liver of three duck species: influence of species and sex. *Environ. Pollut.* 45: 1-15.

King, K.A., and Cromartie, E. 1986. Mercury, cadmium, lead, and selenium in three waterbird species nesting in Galveston Bay, Texas, USA. *Colonial Waterbirds.* 9: 90-94.

Ohlendorf, H.M., Custer, T.W., Lowe, R.W., Rigney, M., and Cromartie, E. (In press a) Organochlorines and mercury in eggs of coastal terns and herons in California, USA. *Colonial Waterbirds.*

Ohlendorf, H.M., Hothem, R.L., Aldrich, T.W., and Krynitsky, A.J. 1987. Selenium contamination of the Grasslands, a major California waterfowl area. *Sci. Total Environ.* 66: 169-183.

Ohlendorf, H.M., Klaas, E.E., and Kaiser, T.E. 1978. Environmental pollutants and eggshell thinning in the black-crowned night heron. In *Wading Birds* (A. Sprunt, IV, J.C. Ogden, and S. Winckler, eds.), pp. 63-82. National Audubon Society Research Report No. 7.

Ohlendorf, H.M., Klaas, E.E., and Kaiser, T.E. 1979. Environmental pollutants and eggshell thickness: anhingas and wading birds in the eastern United States. Special Scientific Report -- Wildlife No. 216. U.S. Fish and Wildlife Service.

Ohlendorf, H.M., Lowe, R.W., Kelly, P.R., and Harvey, T.E. 1986c. Selenium and heavy metals in San Francisco Bay diving ducks. *J. Wildl. Manage.* 50: 64-71.

Ohlendorf, H.M., Marois, K.C., Lowe, R.W., Harvey, T.E., and Kelly, P.R. Environmental contaminants and diving ducks in San Francisco Bay. Symposium on selenium and agricultural drainage implications for the environment (Selenium IV) Berkeley, California.

Ohlendorf, H.M. and Miller, M.R. 1984. Organochlorine contaminants in California Waterfowl. *J. Wildl. Manage.* 48: 867-877.

Ohlendorf and Fleming, 1988. Hazard Evaluation of Environmental Contaminants in Bird Tissues or Eggs from San Francisco Bay Delta.

Presser, T.S., and Ohlendorf, H.M. 1987. Biogeochemical cycling of selenium in the San Joaquin Valley of California. *Environ. Manage.* 11: 805-821.

Vermeer, K.; and Peakall, D.B. 1979. Trace metals in seaducks of the Fraser River Delta intertidal area, British Columbia. *Mar. Pollut. Bull.* 10: 189-193.

White, D.H and Cromartie, E. 1985. Bird use and heavy metal accumulation in waterbirds at dredge disposal impoundments, Corpus Christi, Texas. *Bull. Environ. Contam. Toxicol.* 34: 295-300.

White, D.H., Hofmann, P.S., Hammond, D., and Baumgarten, S. 1988. *Selenium Verification Study, 1986-87: A Report to the State Water Resources Control Board.* California Department of Fish and Game, Sacramento.

APPORTIONING BENEFITS TO POINT SOURCES CHAPTER 7

INTRODUCTION

The benefits estimates presented in previous chapters represent the total benefits expected to occur once water quality control programs have been fully implemented by California and water quality criteria have been achieved for toxic pollutants. Because EPA is developing estimates of costs associated with implementation of the proposed water quality criteria, it is important to estimate the benefits specifically associated with reducing toxic discharges from point sources. This will allow a more consistent comparison of costs and benefits.

This chapter draws on available data to apportion benefits to point and nonpoint sources. Our general approach consists of first using available data to estimate the percent of all toxics loadings coming from point sources. We then adjust this figure by the percentage reduction in point source loadings expected to occur when the toxics criteria are fully implemented by the state. Finally, we use this information to scale the human health, economic, and ecological benefits developed in earlier chapters.

Throughout this chapter, we define point sources to include NPDES permitted sources -- publicly owned treatment works (POTWs), industrial dischargers, and active/inactive mines.[1] Although stormwater discharges are regulated as a point source, they are not included as a point source category in this analysis because they are not explicitly addressed in the available data and

[1] While mines are considered to be a point source subject to NPDES under the Clean Water Act, not all mines in California have been permitted. Loadings reductions for mines (both active and inactive) with major NPDES permits have been estimated, and are used in this analysis, although they do not represent the entire universe of mines in the State. Consequently, some of the benefits estimated in this chapter may not occur in the same time frame as benefits associated with other point sources evaluated here (POTWs and industrial dischargers).

because they are typically not subject to numeric water quality-based effluent limits. Although data sources vary, "other" sources generally include urban runoff, runoff from forestry and agriculture, rangeland runoff, and atmospheric deposition.

This chapter first reviews regional loadings studies to determine how point sources contribute to total loadings of priority toxic pollutants. Second, we apportion economic benefits to point sources using point source contribution estimates averaged across the key pollutants. Next, we qualitatively discuss apportionment of recreational angler health benefits to point sources, examining key pollutants and discussing analytic obstacles that preclude a strict quantitative apportionment of cancer cases and noncancer risks. Finally, we apportion ecological benefits based on estimates developed in Chapter 5.

Summary of Findings

Our research supports the following conclusions:

- Point sources such as POTWs, industrial dischargers, and mines are significant contributors of total toxic pollutants discharged to California surface waters, although other sources (e.g., urban runoff, agricultural runoff) tend to be more significant.

- Point sources are responsible for a large share of toxics loadings to California bays. For bays other than San Francisco Bay, we estimate that point sources account for between 42 and 64 percent of toxics loadings. Point sources account for between five and 30 percent of toxics loadings to freshwater, and between four and 11 percent of loadings to San Francisco Bay.

- We estimate that control of toxics discharged from point sources will yield between $3 million and $65 million per year in economic benefits (recreational fishing and non-use values), with a midpoint best estimate of about $34 million per year.

- Apportioning health risks to point sources is difficult because a number of the most significant pollutants occur in concentrations below detection limits; this precludes tracing the pollutants to point sources and other sources. However, examination of effluent data and literature, as well as discussions with knowledgeable regulatory staff, suggests that a number of health risk drivers -- PCBs, dioxin, pesticides, and mercury -- are discharged, at least in part, by point sources. Despite this finding, representative calculations suggest that the potential health risk reductions associated with control of point sources are likely to be limited unless significant effluent reductions are achieved.

- Point source discharge reductions are likely to yield a number of ecological benefits as well. First, reduced loadings will reduce morbidity/mortality of aquatic and some terrestrial wildlife and improve the integrity of ecosystems in at least 20,000 acres of assessed bays, estuaries, lakes, and wetlands as well as 100 miles of miles of rivers that are now currently impaired. Reduced point source loadings may also improve conditions for fish spawning and/or migration in at least 14,000 acres of bays, harbors, and estuaries; 5,000 acres of lakes; and 50 miles of rivers and streams. Finally, reductions in point source contributions of toxics are expected to improve habitat supporting threatened and endangered species in at least 10,000 acres of bays, harbors and estuaries; 1,700 acres of lakes; and 100 river miles.

These findings are subject to some uncertainty given the limited availability of Statewide data and the overall limitations of the apportionment approach used. First, the extent and diversity of surface water resources and the great number and variety of dischargers make it difficult to draw general conclusions regarding the relative influence of point sources and nonpoint sources discharging to California waters. While available data provide enough information to estimate broad ranges of benefits associated with reducing toxic discharges from point sources throughout the state, the circumstances at a specific waterbody may differ from these general estimates. Second, the apportionment approach used here assumes that reductions in toxic loadings and the resulting benefits are linearly related. As discussed later in this chapter, this may not be true under certain circumstances, although the direction of the bias introduced is unclear.

DETERMINATION OF POINT SOURCE CONTRIBUTIONS TO TOXICS LOADINGS

To apportion the benefits of implementing the toxics criteria to point source dischargers, we first need to estimate the portion of key pollutants that are discharged by point and nonpoint sources. Because California waters are extensive and diverse, it is difficult to make state-wide generalizations about the relative toxic discharge contribution of point sources to all water bodies in the state. Therefore, the sections below discuss three categories of waterbodies: San Francisco Bay, other enclosed bays and estuaries, and freshwater. We chose these three categories because of likely similarities in the profile of discharge sources and because of the need to match the categories for which benefits (e.g., health risks, economic benefits) were estimated.

We performed a literature search to identify studies that address the relative magnitude of point and other discharges of toxics to the three water categories. Available information was limited in two key ways. First, we located many studies of specific discharge categories (e.g., industrial sources) that affect particular waterbodies; however, few of these studies compare the relative contribution from all sources (point and other). Second, the size and diversity of water resources in California precluded performing a comprehensive study of point source contributions across the

state. Instead, all of the studies and data located apply to site-specific waterbodies or segments of waterbodies. Except in the case of San Francisco Bay, this requires that we generalize from studies of one waterbody to other similar waterbodies in California.[2]

San Francisco Bay

The sections below review the data sources used to estimate point and other source loadings of toxic pollutants to San Francisco Bay, the results of the data analysis, and uncertainties and limitations of the analysis.

---

[2] In addition to the studies discussed in this chapter, we also reviewed the following documents, but found no information relevant to the apportionment analysis: Association of Bay Area Governments, *State of the Estuary: A Report on Conditions and Problems in the San Francisco Bay/Sacramento-San Joaquin Delta Estuary*, San Francisco Estuary Project, June 1992; Association of Bay Area Governments, *Comprehensive Conservation and Management Plan*, San Francisco Estuary Project, June 1994; California Environmental Protection Agency, *Mass Emission Reduction Strategy for Selenium*, Staff Report, Basin Planning and Protection Unit, October 12, 1992; Cross, J., et al., *Annual Report 1990-91 and 1991-92*, Southern California Coastal Water Research Project, November 1992; Davis, J., et al., "Priority Pollutant Loads from Effluent Discharges to the San Francisco Estuary," *Water Environment Research*, Vol. 64, No. 2, March/April 1992; Flegal, A. Russell, et al., "Comparable Levels of Trace Metal Contamination in Two Semi-Enclosed Embayments: San Diego Bay and South San Francisco Bay," *Environmental Science and Technology*, Vol. 27, No. 9, 1993; Los Angeles County Public Works, *Report of Stormwater Monitoring: Winter of 1994-95*, Environmental Programs Division, March 1996; Southern California Association of Governments, *The State of Santa Monica Bay, Part Two: Assessment of the Management Framework*, Santa Monica Bay Project, November 1988; State Water Resources Control Board, *1994 Section 305(b) Water Quality Report for the State of California*, October 1994; State Water Resources Control Board, *Status of the Bay Protection and Toxic Cleanup Program*, Staff Report, State of California, November 1993; U.S. EPA, *Los Angeles River Loadings of Trace Metals and Synthetic Organics*, Office of Research and Development, Report No. 600/X-91/030, April 1991; WE&T Staff, "California Water Boards Address Impaired Rivers," *Water Environment and Technology*, Vol. 7, No. 5, May 1995; Wranic, A.D., et al., "Pollutant Loadings Generated by Nonpoint Sources in the Santa Monica Bay Drainage Basin: A Case Study," *Water Resources Management*, No. 8, 1994.

Data Sources

Two studies serve as the foundation for the San Francisco Bay toxics apportionment:

- Davis et al., *Status and Trends Report on Pollutants in the San Francisco Estuary* (1991)[3]; and
- National Oceanic and Atmospheric Administration (NOAA), *National Coastal Pollutant Discharge Inventory* (1988).[4]

Below, we discuss the loadings estimation methodology used in the two studies and the resulting characterization of relative point source and other source contributions to overall toxic loadings.

Davis Study

The *Status and Trends Report on Pollutants in the San Francisco Estuary* uses existing data to establish an upper and lower bound range for several toxic contaminants originating from both point and nonpoint sources. Davis et al. estimate that 5,000 to 40,000 metric tons of at least 65 different pollutants are released annually into the San Francisco Estuary. These pollutants include trace elements such as arsenic, lead, and mercury, and organic compounds such as pesticides.

Davis used effluent monitoring data from the National Pollutant Discharge Elimination System (NPDES) to estimate municipal (POTW) and industrial loadings. These data were gathered from 1984 through 1987. Other (nonpoint) sources of pollution, as defined by Davis et al., consist of urban runoff, nonurban runoff, riverine inputs, atmospheric deposition, dredged material, and oil spills. A study by Gunther et al. (1987) provided the range estimates for urban runoff.[5] This study used data on precipitation, land use, runoff coefficients and pollutant concentrations originally gathered by NOAA and the National Urban Runoff Program (1983 data) to calculate loadings.

---

[3] Davis, J.A., et al., *Status and Trends Report on Pollutants in the San Francisco Estuary*, prepared by the San Francisco Bay-Delta Aquatic Habitat Institute for the San Francisco Estuary Project, U.S. EPA, March 1991.

[4] NOAA, *The National Coastal Pollutant Discharge Inventory: Estimates for San Francisco Bay. Data Summary*, Ocean Assessments Division, National Oceanic and Atmospheric Administration, June 1988.

[5] Gunther, A.J., et al., *An Assessment of the Loading of Toxic Contaminants to the San Francisco Bay-Delta*, prepared by the Aquatic Habitat Institute, 1987.

Nonurban runoff originates from agricultural, range, and forest lands. Davis used a NOAA model that factors in sediment loss from nonurban lands and average trace metal concentrations in soil to estimate runoff loadings to the Bay. Since NOAA chose a high precipitation year (1982) as its modeling year, these estimates became the high ends of the ranges. To calculate the low ends of the ranges, Davis et al. divided the high end figures by 11.5, a factor which accounts for values that one might expect in a lower precipitation year.

Davis considers all pollutants transported past the city of Sacramento by the Sacramento River and past the city of Vernalis by the San Joaquin River as riverine inputs to the Delta. Loadings estimates for the San Joaquin River came from water quality data collected by the U.S. Geological Survey under the San Joaquin Valley Drainage Program (SJVDP). Under the SJVDP at Vernalis, scientists collected samples twice per month from June 1985 to March 1987. A study conducted by the California Department of Water Resources in 1987-88 on selenium cycling serves as the only source of information on loadings from the Sacramento River.

Given the lack of site-specific data for the San Francisco Bay area, Gunther et al. (1987) applied deposition data measured in other parts of the U.S. when calculating their range of load estimates. Davis incorporates these data.

Finally, in calculating total pollutant loads to the Estuary, Davis examined the possible quantities that dredging activities might contribute. They believed that dredging could redistribute buried pollutants to the extent that these pollutants would then become bioavailable to estuarine biota. Gunther et al. (1987) estimated the pollutant loads derived from dredging activities in the Estuary. Other studies suggest that these estimates may be highly conservative.

NOAA Study

The Strategic Assessment Branch of NOAA developed the *National Coastal Pollutant Discharge Inventory* (NCPDI) to estimate pollutant loadings for all point, nonpoint, and riverine sources located in coastal counties throughout the U.S. NOAA estimates that approximately 22,000 metric tons of toxic substances are released annually into the San Francisco Estuary. As with the study by Davis, these substances include a variety of trace elements and synthetic compounds. NOAA's point source estimates reflect discharges in a 1985 base year; the estimates for nonpoint sources reflect discharges in a 1982 base year.

Similar to Davis, NOAA used effluent monitoring data from the National Pollutant Discharge Elimination System (NPDES) to estimate municipal and industrial loadings in the base year 1985.

Other sources of pollution, as defined by NOAA, consist of urban runoff, nonurban runoff, and riverine inputs. NOAA used four data sources to obtain its urban runoff estimates. First, NOAA examined the 1980 Census of Population for definitions of urban areas and estimates of total county and city urban land area and population. Second, the U.S. EPA Office of Water furnished the 1982 Needs Survey, a biennial survey of all POTW wastewater and stormwater conveyance and treatment.

Third, NOAA's National Climatic Data Center provided detailed weather station records and precipitation data for estimating runoff. Fourth, the U.S. Geological Survey's Land Use Data Analysis system supplied information on urban land use activities. Combining these values with runoff coefficients and pollutant concentrations yielded the final urban runoff estimates.

To estimate the contribution of nonurban runoff to loadings, NOAA examined those areas deemed most likely to contribute significantly to loadings. These areas fall into one of four categories: areas where farming, silviculture or other activities have exposed bare soil to wind, rain, and surface runoff; areas where soil is most erodible; areas where large amounts of chemical fertilizers and pesticides have been applied to the land surface; and areas where sufficient runoff exists to transport these pollutants. To compute the pollutant loadings, NOAA collected data on the topography, soils, climate, land uses and management practices of all the areas studied. NOAA obtained the majority of its data from three sources: the U.S. Geological Survey's Land Use Data Analysis system, the U.S. Department of Agriculture's 1982 National Resource Inventory, and a study by Shacklette and Boerngen (1984). In tabulating the specific pollutant loadings to the Estuary, NOAA multiplied the quantity of eroded sediment by the soil pollutant concentration.

Riverine inputs to the Estuary originate primarily from the Sacramento and San Joaquin Rivers. To estimate the share of pollutant loadings stemming from upstream sources, NOAA obtained water quality data from the U.S. Geological Survey (USGS) National Stream Quality Accounting Network (NASQAN). NOAA used the raw USGS data in a simulation model to estimate loadings to San Francisco Bay.

Results for San Francisco Bay

We use the NOAA and Davis data to estimate relative loadings of toxics from point and other sources discharging to San Francisco Bay. Exhibit 7-1 summarizes these estimates. Each entry in the table shows the percentage of all loadings estimated to be from point sources. For example, NOAA estimates that five percent of the zinc discharged to San Francisco Bay originates from point sources, while Davis estimates that the point source percentage for zinc falls between four and 19 percent.[6]

In general, the exhibit shows that point sources contribute a smaller share of toxic loadings than other sources. This is best summarized by developing an average percent contribution across the pollutants for which data are available. A straight average of the point source contribution percentages would be misleading because some pollutants are more toxic than others. For example, a small quantity of mercury discharged to the Bay has much greater human health, ecological, and economic implications than the same quantity of copper. A straight average would not recognize

[6] Appendix F of this document provides the detailed loadings data from the NOAA and Davis studies, as well as other data to be review later in this chapter.

Exhibit 7-1

POINT SOURCE CONTRIBUTIONS TO SAN FRANCISCO BAY

Pollutant	NOAA (1)	Davis et al. (2)	
		Lower Bound	Upper Bound
Zinc	5%	4%	19%
Copper	6%	4%	12%
Nickel	N/A	26%	28%
Lead	7%	2%	8%
Chromium	3%	1%	6%
Arsenic	11%	4%	6%
Cadmium	16%	30%	65%
Selenium	N/A	28%	28%
Mercury (3)	45%	26%	52%
Chlorinated Hydrocarbon Pesticides	51%	N/A	N/A
Toxic-Weighted Average	**7% - 11%***	**2%**	**7%**

(1) NOAA, *The National Coastal Pollutant Discharge Inventory: Estimates for San Francisco Bay*, Data Summary, Ocean Assessments Division, National Oceanic and Atmospheric Administration, June 1988. NOAA assessed the following point sources: POTWs, industrial effluents, and power plant emissions. NOAA assessed the following other sources: urban runoff, cropland runoff, forestland runoff, rangeland runoff, and upstream sources.

(2) Davis, J.A., et al., *Status and Trends Report on Pollutants in the San Francisco Estuary*, prepared by the San Francisco Bay-Delta Aquatic Habitat Institute for the San Francisco Estuary Project, U.S. EPA, March 1991. Davis et al. assessed the following point sources: municipal effluents and industrial effluents. Davis et al. assessed the following other sources: upstream sources, urban runoff, nonurban runoff, atmospheric deposition, dredged material, and oil spills.

(3) The NOAA data show large mercury loadings associated with riverine inputs to the Bay. We classified 46.34 percent of these riverine loadings as point sources given that upstream mines are the likely original source of the mercury. The 46.34 percent figure is based on the average point source contribution for several metals discharged to the Sacramento River (see Exhibit 7-4).

* Lower bound of range based on median toxic weight for pesticides (100); upper bound of range based on mean weight for pesticides (5,300).

this difference and potentially would allow high-quantity/low-consequence pollutants to drive our assessment of point source contributions. Therefore, we develop a toxicity-weighted average based on the toxicity weights used in the cost analysis.[7] Toxic weight factors were derived for toxic pollutants primarily from EPA's chronic freshwater aquatic life criteria and toxicity values. However, EPA human health criteria also were used in cases where a human health criterion had been established for the consumption of fish. Generally, toxic weights were derived by EPA through standardizing these criteria using copper as the standard pollutant (the original EPA criterion for copper, 5.6 ug/L, was used as the water quality criterion and the standardization factor).

Toxic weights for pollutants were taken from the *Assessment of Compliance Costs Resulting from Implementation of the Final Great Lakes Water Quality Guidance* (March 13, 1995). The toxic weights used in the Great Lakes analysis represent toxic weights calculated by EPA's Office of Science and Technology (OST) in 1988 using pollutant criteria that have been used in various EPA regulatory efforts.[8]

The process of developing a toxicity-weighted average is illustrated in Exhibit 7-2, using the NOAA data. We follow three steps: (1) we weight each "raw" loadings estimate from the NOAA and Davis data by the relevant weighting factor shown in Exhibit 7-2; (2) we sum the weighted loads to arrive at a total toxic loadings estimate for point and other sources; and (3) we estimate the proportion of all loadings (point and other) that come from point sources.

In the case of chlorinated hydrocarbon pesticides, we need to estimate a weight for the entire class of pollutants.[9] The relevant weights range from a low of 0.35 for 2,4,6 trichlorophenol to a high of 57,000 for dieldrin. Because of this range we use two weights in a sensitivity analysis: a weight of 100 representing the median of the distribution, and a weight of 5,300 representing the mean of the distribution.

---

[7] SAIC, *Analysis of Potential Costs Related to the Implementation of the California Toxics Rule, Final Draft*, prepared for the U.S. Environmental Protection Agency, May 1997.

[8] National water quality criteria have changed over the years, resulting in corresponding changes in toxic weights. Also, because California point sources discharge to both freshwater and saltwater bodies of water, two different sets of toxic weights would need to be covered. To maintain a general level of consistency between the CTR and previous rules, this study used previously calculated toxic weights.

[9] NOAA's estimate for chlorinated hydrocarbon pesticides includes fifteen different pesticides, such as DDT and dieldrin.

Exhibit 7-2

DERIVATION OF TOXIC-WEIGHTED LOADINGS

Pollutant	Toxicity Weight	Point Sources			Other Sources			Total From All Sources	
		Raw Loadings (tons)	Toxic-Weighted Loadings	Percent of Total	Raw Loadings (tons)	Toxic-Weighted Loadings	Percent of Total	Total Loadings	Percent of Total
Arsenic	4	18.14	72.58	11%	140.62	562.46	89%	635.04	100%
Cadmium	5.2	12.70	66.04	16%	68.95	358.52	84%	424.57	100%
Chromium	35.5	32.66	1,159.39	3%	1,236.51	43,895.94	97%	45,055.34	100%
Copper	0.47	55.34	26.01	6%	948.92	445.99	94%	472.00	100%
Lead	1.8	41.73	75.12	7%	525.27	945.48	93%	1,020.59	100%
Mercury	500	4.38	2,190.00	45%	5.40	2,700.00	55%	4,890.00	100%
Zinc	0.051	143.34	7.31	5%	2,623.61	133.80	95%	141.11	100%
Chlorinated Hydrocarbon Pesticides	100	0.57	56.52	51%	0.53	53.34	49%	109.86	100%
Sum of Weighted Loadings			3,652.97	7%	N/A	49,095.55	93%	52,748.51	100%

Notes:

1) Toxic weights obtained from: SAIC, *Analysis of Potential Costs Related to the Implementation of the California Toxics Rule*, prepared for the U.S. Environmental Protection Agency, May 1997.

2) Point sources are defined as POTWs, industrial effluents, and power plant emissions. Other sources are defined as urban runoff, cropland runoff, forestland runoff, rangeland runoff, and upstream sources.

Source: NOAA, *The National Coastal Pollutant Discharge Inventory: Estimates for San Francisco Bay*, Data Summary, Ocean Assessments Division, National Oceanic and Atmospheric Administration, June 1988.

Exhibit 7-1 lists the resulting toxicity-weighted loadings estimates. As shown, the toxicity-weighted estimate of point source contributions ranges from about 2 percent (the lower bound of the Davis data) to 11 percent (based on the NOAA data). The weighted average for the Davis data is remarkably low relative to the percentages for individual pollutants. This is the result of the large share of weighted loadings accounted for by chromium, a pollutant for which point sources contribute only a small portion of total loadings.

Uncertainties and Limitations

Our analysis using the NOAA and Davis data to estimate point source contributions of toxics is subject to several uncertainties and limitations:

> First, detection limits in the sampling data used in the NOAA and Davis studies required simplifying assumptions. When pollutants were below detect limits, Davis calculated the lower end of each discharge range by counting values below detection limits as zero, and calculated the upper end of each range by assuming that below-detect values indicated a concentration equal to the detection limit. NOAA did the same, but assumed that concentrations were equal to one-tenth the detection limit.[10] It is difficult to determine the direction or magnitude of the bias introduced by these assumptions.
>
> Second, the NOAA and Davis data do not include specific estimates for many sources, both point and nonpoint. Most notably, the estimates do not include point source mine drainage, a significant source of toxic metals. In addition, the NOAA data do not include atmospheric deposition or dredging. Again, it is difficult to determine the direction of the bias introduced by these limitations, although the variety of other (nonpoint) sources absent in the analysis may tend to overstate the importance of point sources.
>
> While both studies include riverine inputs as a nonpoint source, discharges to these rivers may have originated as point or nonpoint sources. Again, it is difficult to characterize the degree or direction of the bias without further study.

---

[10] No detect values for PCBs were especially problematic in the Davis data. PCBs were detected in only 0.15%, or one in 677 samples. We therefore chose not to use these data in our apportionment analysis.

> The data from both studies are based on discharges from the early and mid-1980s, and therefore may not be entirely representative of current conditions in San Francisco Bay.
>
> It is uncertain whether toxics discharged upstream of the Delta actually reach the Bay, or are, instead, bound up in sediments for long periods of time. It is unclear how the NOAA and Davis studies deal with toxics fate and transport. If fully conservative fate and transport assumptions were made, this would tend to overstate the amount of toxics which actually reach the Bay.

In addition, the Davis study has several specific shortcomings. Most notably, despite the fact that the Sacramento River contributes 80 percent of the freshwater inflow to the Estuary, and probably carries numerous toxic pollutants, Davis did not include estimates for the River. Because much of the impairment of the Sacramento is attributable to mines, this omission likely leads us to understate point source contributions.[11] Also, in estimating urban runoff, Davis did not have local runoff pollutant concentrations; as an alternative, the study uses national averages from the National Urban Runoff Program (1983 data). Finally, as stated earlier, Gunther and Davis used atmospheric deposition rates from other parts of the country to estimate loads to the Estuary. Use of these rates from the rest of the country would tend to overestimate loadings from this source as there are few sources of airborne toxics upwind from the Bay area. If values from the upper mid-west were used, the overestimate could be large.[12]

Other Bays and Estuaries

Data Sources

To estimate the contribution of point source loadings of toxics to bays other than San Francisco Bay, we use the same set of NOAA data (the National Coastal Pollutant Discharge Inventory) used for San Francisco Bay. NOAA data are available for five "other" bays: San Diego, Humboldt, Monterey, Santa Monica, and San Pedro.[13]

---

[11] Mine drainage contributes significantly to the impairment of the Sacramento River, especially for copper, zinc, and cadmium. See California Regional Water Quality Control Board, Central Valley Region, *Inactive Mine Drainage in the Sacramento Valley, California*, 1992.

[12] Personal communication with Dave Smith, U.S. EPA, Region IX, San Francisco, California, February 20, 1996.

[13] Note that only two of these bays -- San Diego and Humboldt -- are enclosed bays that are therefore covered by the rule. We assume that the data for the non-enclosed bays generally will be applicable to enclosed bays.

Results for Other Bays and Estuaries

Exhibit 7-3 summarizes the relative contribution of point sources to "other" California bays. In general, the toxicity-weighted average contribution of toxic loadings stemming from point sources ranges greatly, from 23 percent (for Monterey Bay) to 93 percent (for Santa Monica Bay). A pattern clearly evident in the data is the difference between urban and non-urban bays. In general, urban bays tend to have a greater portion of their toxics loadings originating from point sources than do less urbanized bays. Urban area discharges typically come from point sources such as POTWs, storm water discharges, electric power plants, and industrial facilities. San Diego, Santa Monica, and San Pedro Bays (the latter two being near Los Angeles) can be treated as representative of other urban bays covered by the CTR (including Mission Bay, Upper and Lower Newport Bay, and Los Angeles-Long Beach Harbor). As shown, the three bays for which we have data all have average point source contributions of about 90 percent.

Non-urban bays are less populated and have different dischargers than urban bays. A larger portion of their toxic loadings originate from nonpoint sources such as farming and forestry runoff. For example, the largest town surrounding Humboldt Bay is Eureka, which contains fewer than 100,000 inhabitants. Most of the land surrounding Humboldt Bay is designated as national forest or wilderness area. For these reasons, Humboldt and Monterey Bay can be treated as representative of the non-urban bays covered by the rule (Bodega Harbor, Morro Bay, Drake's Estero, Tomales Bay, and Carmel Bay). As shown, the two bays for which we have data have average point source contributions of between 23 and 33 percent.

Uncertainties and Limitations

Above, we noted limitations that apply to the NOAA data on San Francisco Bay; these limitations are also applicable to the data for other bays. In addition, it is noteworthy that the estimated point source contributions for San Francisco Bay are much lower than for the other urban bays. The reason for this discrepancy is not readily apparent. Most likely, the contrast is attributable to the hydrologic difference between San Francisco Bay and the other bays. San Francisco Bay is a major estuarine system and represents the drainage basin for a massive geographic area comprising urban, agricultural, and other land uses. In addition, the area is fed by two major rivers (the San Joaquin and the Sacramento) that contribute significantly to loadings. In contrast, the other bays are much smaller waterbodies that in many cases do not represent major drainage basins and are fed by smaller or even seasonal rivers. Overall, this will enhance the relative importance of point sources.

Exhibit 7-3

CONTRIBUTION OF POINT SOURCES TO OTHER CALIFORNIA BAYS

	Non-Urban Bays (1)		Urban Bays (2)		
Pollutant	**Monterey Bay**	**Humboldt Bay**	**San Diego Bay**	**Santa Monica Bay**	**San Pedro Bay**
Arsenic	57%	33%	88%	90%	87%
Cadmium	84%	40%	100%	100%	100%
Chromium	15%	35%	95%	88%	88%
Copper	16%	17%	87%	89%	79%
Lead	30%	19%	41%	67%	27%
Mercury	76%	9%	90%	88%	81%
Zinc	24%	27%	81%	78%	71%
Chlorinated Hydrocarbon Pesticides	N/A	N/A	93%	99%	94%
Toxic-Weighted Average	**23%**	**33%**	**91% - 92%***	**88% - 93%***	**83% - 89%***

(1) NOAA, *The National Coastal Pollutant Discharge Inventory, Summary of Pollutant Discharges in West Coast Study Area by Estuarine Watershed*, circa 1982/1984; obtained on disk from Mr. Percy Pacheco, Office of Ocean Resources Conservation and Assessment. NOAA assessed the following point sources: POTWs, industrial effluents, and power plant emissions. NOAA assessed the following other sources: urban runoff, cropland runoff, forestland runoff, rangeland runoff, irrigation return flows, and upstream sources.

(2) NOAA, *The National Coastal Pollutant Discharge Inventory: Estimates for Santa Monica Bay, San Pedro Bay, and San Diego Bay*. Data Summary, Ocean Assessments Division, National Oceanic and Atmospheric Administration, July 1988.

Notes:

* Lower bound of range based on median toxic weight for pesticides (100); upper bound of range based on mean weight for pesticides (5,300).

Freshwater

Developing general conclusions on the relative loadings contributions of point and nonpoint sources discharging toxics to freshwater is difficult. California has a diverse interior landscape and numerous sources of toxic pollutants, including farming, mining, and forestry, as well as residential, industrial, and commercial establishments. As a result, available data show significant variability in overall point source contributions of toxics depending upon the specific location. For example, discharges from mines, which are regulated as point sources, are significant to the Sacramento River, while other pollution sources associated with agricultural drainage dominate toxics loadings to the San Joaquin River. This diversity makes it difficult to generalize about the role of point sources in overall discharges of toxics to freshwater. Ideally, we would characterize the benefits of toxics control and the sources of toxics loadings for each major freshwater resource and apportion the benefits based on the distribution of loadings by source. Such an analysis, however, is beyond the scope of this analysis.

Other uncertainties include the fact that data are not available for assessing point and nonpoint contributions of toxics. While such inter-source data are available for key coastal waterbodies, little information exists for California freshwater generally, or even for specific bodies of freshwater.

Because of these difficulties, we rely on a limited set of data to develop a relatively broad range of point source contributions to freshwater. First, we consider loadings data on two major rivers in California. Second, we rely on other information from our analysis of the Water Quality Assessment data base.

Loadings Data

The Central Valley Regional Water Quality Control Board (CVRWQCB) assembled data on the principal sources discharging several metals to the Sacramento and the San Joaquin Rivers.[14] The sources analyzed included the following:

---

[14] Central Valley Regional Water Quality Control Board, *Mass Emission Strategy Load Estimates*, internal staff report, no date. Most of the data in this report are based on California Regional Water Quality Control Board, Central Valley Region, *A Mass Loading Assessment of Major Point and Nonpoint Sources Discharging to Surface Waters in the Central Valley, California, 1985*, Draft Staff Report, October, 1988.

Urban runoff calculated for 19 major cities in the Central Valley region;

Agricultural drainage based on monitoring data collected by the Regional and State water quality boards in the mid 1980s (for the Sacramento River) and modeled loadings (for the San Joaquin River);

Mining drainage based on monitoring data for 34 mining sites in the Sacramento River valley and one mine in the San Joaquin River valley;

Industrial and municipal point sources based on effluent concentration data from the Sacramento County sewage treatment plant and flow data for the individual NPDES-permitted dischargers.[15]

The CVRWQCB report points to a number of uncertainties and shortcomings in the data reported. First, the urban runoff estimates used probably understate total runoff discharges given that only a subset of cities in the Central Valley region were incorporated and "below detect" pollutant concentration values were counted as zero. Second, mining drainage estimates for the San Joaquin River include only one mine for which samples were taken at only one point in time. Finally, use of effluent concentration data from the Sacramento County POTW may not be representative of effluent from other facilities, although the direction of the bias is unclear.

Because land use around the Sacramento and San Joaquin Rivers is diverse, the percentage contribution of toxic pollution from point sources varies greatly. Exhibit 7-4 shows the percentage of loadings attributable to point sources on each river. For all pollutants, point source contributions for the Sacramento River are greater than those for the San Joaquin. This is explained by the strong influence of point source mine discharges on the Sacramento.[16] Using a toxicity-weighted average across all five pollutants indicates that about 46 percent of loadings to the Sacramento River are associated with point sources, while only three percent of loadings to the San Joaquin River are associated with point sources.

---

[15] Facility-specific loadings were not used because: (a) monitoring was performed for only a subset of pollutants, and (b) much of this sampling used high detection limits.

[16] As noted earlier, mines are regulated as point sources. However, NPDES permits have not been issued for all mines. Therefore, all toxic discharges may not be reduced immediately under the point source controls assumed in the CTR cost analysis.

Exhibit 7-4

POINT SOURCE CONTRIBUTIONS TO FRESHWATER RIVERS

Pollutant	Sacramento River	San Joaquin River
Arsenic	22%	3%
Cadmium	82%	6%
Copper	72%	3%
Lead	6%	3%
Zinc	73%	7%
Toxic-Weighted Average	**46%**	**3%**

(1) Central Valley Regional Water Quality Control Board, *Mass Emission Strategy - Load Estimates*, no date. The CVRWQCB assessed two point sources, inactive mine drainage and NPDES discharges. The CVRWQCB assessed two other sources, urban runoff and agricultural drainage.

If we assume that the Sacramento River data are representative of mining areas, and that the San Joaquin data are representative of areas not heavily influenced by mines, we can develop a weighted average of the available data. This average weights the point source contribution in mining areas (46 percent across all pollutants) by the percentage of California freshwater influenced by mining, and the point source contribution in non-mining areas (3.4 percent) by the percentage of waters not influenced by mines. This calculation can be implemented using data from our analysis of California's Water Quality Assessment data base. Data compiled for Exhibit 2-5 of Chapter 2 indicate that 61 percent of lake acreage and 25 percent of river miles are adversely influenced by mining. Using this information, we can calculate the following:

Lakes: (0.61 * 0.46) + (0.39 * 0.034) = 0.29, i.e., 29 percent of loadings to lakes are attributable to point sources;

Rivers: (0.25 * 0.46) + (0.75 * 0.034) = 0.14, i.e., 14 percent of loadings to rivers are attributable to point sources.

Water Quality Assessment Data

To develop a point source contribution range for freshwater, the above loadings information should be considered in the context of other available information. Most notably, the Water Quality Assessment data base analysis from Chapter 2 provides useful information about sources of toxics to California freshwaters. Exhibit 7-5 summarizes data reported earlier in Chapter 2. The table

shows the various sources associated with toxics-impaired freshwater. Two key factors impede our ability to draw precise conclusions from these data. First, a given waterbody can be affected by more than one source type (e.g., a lake acre can be influenced by both mining and urban runoff). Second, the WQA data do not report actual loadings, only the association between a waterbody and a particular source category; i.e., mining and urban runoff may both affect a waterbody, but one may be much more important than the other.

Exhibit 7-5

MAJOR SOURCES OF TOXIC POLLUTANTS IN CALIFORNIA FRESHWATER RESOURCES

	Lakes & Reservoirs (acres)	Share of Total Toxics-Impaired Area	Rivers & Streams (miles)	Share of Total Toxics-Impaired Area
Industrial	295	<1%	273	7%
Mining	106,748	61%	930	25%
Municipal	0	0%	276	7%
Other Point Sources	0	0%	4	<1%
Agriculture	2,410	1%	2,260	60%
Hydro/Habitat Modification	0	0%	40	1%
Land Development	26,500	15%	106	3%
Land Disposal	0	0%	19	1%
Other Nonpoint Sources	64,350	37%	987	26%
Storm Sewers	0	0%	185	5%
Urban Runoff	7,995	5%	537	14%

Source: EPA analysis of California 1994 WQA data.

Despite these drawbacks, the data clearly show that point sources play a significant role in toxics loadings to freshwater. Most notably, mines affect 61 percent of impaired lakes and 25 percent of impaired rivers. Likewise, industrial and municipal point sources adversely affect a significant share of impaired rivers. Contributions from other sources, however, are still equally important for lakes (e.g., other nonpoint sources and urban runoff) and possibly more important than point sources for rivers, where about 60 percent of all impaired river miles are associated with agricultural runoff. Taken together, this information suggests that point sources, especially mines, are important contributors of toxics loadings to freshwater, but other sources dominate. This finding is generally consistent with the loadings data presented above.

Summary of Point Source Contributions to Freshwater Loadings

We can merge the available information to establish a range of point source contributions to freshwater loadings. For the lower bound, we assume that point sources contribute at least five percent of toxics loadings, based on the CVRWQCB data for the San Joaquin River. For the upper bound, we assume that point sources account for 30 percent of toxics loadings, based on the lake-weighted average of the CVRWQCB data. We use this range -- five to 30 percent -- to apportion economic benefits below.

APPORTIONMENT OF ECONOMIC BENEFITS

The analysis of point source contributions to total toxics loadings can be used to estimate the portion of economic benefits (see Chapter 4) attributable to controls at point sources. However, the apportionment of economic benefits cannot be developed on a pollutant-specific basis. It is difficult to estimate pollutant-specific effects on aquatic life and translate them into economic measures (such as recreational fishing benefit or non-use benefits). Therefore, we develop an apportionment analysis that uses average point source contributions and loadings reductions across regulated pollutants. In general, we follow three steps:

> First, we sum the use and non-use benefits for three waterbody categories: (1) San Francisco Bay, (2) other bays and estuaries, and (3) freshwater and saline lakes.[17]
>
> Next, we multiply the economic benefit estimate for each waterbody category by the relevant point source contribution range. The range used represents an average across the pollutants for which data are available. In effect, this provides a rough estimate of the benefits that would be realized if all point source discharges were reduced to meet water quality standards.
>
> Finally, we multiply by the percentage reduction in point source discharges as estimated in the cost analysis performed for this rule.[18] Specifically, we use the average loadings reduction across the 50 pollutants addressed in the cost analysis. We develop the toxic-weighted average load reduction by dividing the sum of the toxic-weighted loadings reductions by the sum of the

---

[17] The latter category includes freshwater rivers and lakes as well as saline lakes; we include saline lakes in this category because the profile of point and nonpoint discharges is likely to have more in common with freshwater lakes than with bays and estuaries.

[18] SAIC, *Analysis of Potential Costs Related to the Implementation of the California Toxics Rule*, prepared for the U.S. EPA, May 1997.

toxic-weighted baseline loadings. We develop this estimate for both the upper and lower bound control scenarios from the cost analysis. Exhibit 7-6 presents the reductions for individual pollutants and the estimated average reduction -- 27 percent in the lower bound and 31 percent in the upper bound.

This approach can be summarized with the following equation:

Economic Benefit Estimate	*	Percent of Toxics Discharged by Point Sources	*	Percent Reduction Of Total Toxics Discharges At Point Sources[19]	=	Benefits From Controls Implemented by Point Sources

Exhibit 7-7 shows how we combine these pieces of information to estimate the total economic benefits attributable to point source control. As shown, we estimate that control of toxics discharged from point sources will yield between $3 million and $65 million per year in economic benefits. The method and results differ somewhat for each waterbody category. Below, we discuss each category in more detail.

San Francisco Bay

To estimate the benefits attributable to point source control in San Francisco Bay, we use the toxic-weighted average of the point source contributions for individual pollutants (see Exhibit 7-1). For a lower bound, we use the mid-point of the estimates derived from the Davis data -- 4 percent (the mid-point of 1.5 percent and 7.09 percent, the unrounded Davis results). As an upper bound, we use the higher estimates from the NOAA study -- 11 percent.

We then multiply by the range in point source reduction of toxic loadings (27 to 31 percent) to estimate the total benefits attributable to point source control. As shown, the range is very broad, reflecting the uncertainty inherent in the estimates. Specifically, we estimate that point source controls in San Francisco Bay will yield between $69,000 and $2 million per year in recreational fishing benefits and non-use benefits.

---

[19] Calculating the gross change in water quality attributable to point source controls requires two pieces of information: (1) the percent of toxics discharged by point sources; and (2) the percent reduction of total toxics discharges at point sources. The first piece of information only identifies the portion of water quality changes attributable to point source discharges versus nonpoint source discharges. To calculate the gross change, an estimate of the reduction in toxics achieved through point source controls is also needed.

Exhibit 7-6

BASELINE TOXIC-WEIGHTED LOADINGS AND LOAD REDUCTIONS

Pollutant	Toxicity Weight	High			Low		
		Baseline Loadings	Reductions	Percent Reduction	Baseline Loadings	Reductions	Percent Reduction
Arsenic (As)	4.00	2,635,683	0	0.0%	307,983	0	0%
Cadmium (Cd)	5.20	280,642	0	0.0%	75,867	0	0%
Chromium VI (Cr-VI)	35.50	4,936,864	682,996	13.8%	2,171,424	399,958	18%
Copper (Cu)	0.47	258,616	47,103	18.2%	217,637	8,034	4%
Lead (Pb)	1.80	644,423	257,842	40.0%	127,664	0	0%
Mercury (Hg)	500.00	2,390,662	1,699,029	71.1%	1,661,481	1,092,898	66%
Nickel (Ni)	0.04	81,083	24,578	30.3%	11,883	0	0%
Selenium (Se)	1.10	54,473	7,980	14.6%	5,913	0	0%
Silver (Ag)	47.00	12,098,544	6,176,143	51.0%	2,041,181	214,546	11%
Zinc (Zn)	0.05	132,997	14,127	10.6%	65,905	0	0%
1,2 Dichlorobenzene	0.01	518,483	22,631	4.4%	0	0	
1,3 Dichlorobenzene	1.00	5,647,941	0	0.0%	0	0	
1,4 Dichlorobenzene	1.00	172,888	0	0.0%	596	0	0%
1,4-Dichlorobenzene	1.00	0	0		0	0	
2,4,6 Trichlorophenol	0.35	384	0	0.0%	0	0	
4,4'-DDD	760.00	8,804	6,867	78.0%	8,804	0	0%
4,4'-DDT	6,500.00	114,842	72,287	62.9%	104,576	0	0%
Aldrin	50.00	118,039	116,066	98.3%	118,026	115,533	98%
alpha-BHC	100.00	195,477	135,466	69.3%	191,932	135,369	71%
alpha-Endosulfan	100.00	3,883	1,071	27.6%	0	0	
Benzene	0.02	1,329	0	0.0%	200	0	0%
beta-BHC	100.00	12,544	0	0.0%	0	0	
Bromoform	1.00	22,188	2,829	12.8%	20,005	0	0%
Butylbenzyl-pthalate	1.00	0	0		0	0	
Chlordane	2,300.00	1,174	0	0.0%	0	0	
Chlorobenzene	0.00	0	0		0	0	
Chlorodibromomethane	1.00	55,576	9,084	16.3%	55,427	8,202	15%
Chloroform	0.00	3,436	58	1.7%	480	0	0%
delta-BHC	1.00	0	0		0	0	
Dichlorobromomethane	1.00	74,218	282	0.4%	79,468	0	0%
Dichloromethane	0.00	0	0		0	0	
Dieldrin	57,000.00	50,838	0	0.0%	0	0	
Endosulfan	100.00	221	41	18.3%	0	0	
Endrin	98.00	1,436	186	12.9%	836	0	0%
Fluoranthene	0.92	205,844	830	0.4%	0	0	
Fluorene	0.70	0	0		0	0	
gamma-BHC	70.00	32,823	4,249	12.9%	25,884	0	0%
Heptachlor	4,100.00	4,364	0	0.0%	2,584	0	0%
Heptachlor epoxide	1.00	0	0	0.0%	0	0	
Hexachlorobenzene	720.00	117,285	110,933	94.6%	0	0	
Lindane gamma-BHC	70.00	0	0		0	0	
Methylene chloride	0.00	1,078	3	0.3%	4	0	0%
PCBs	7,490.00	4,974	0	0.0%	0	0	
Pentachlorophenol	0.50	6,527	738	11.3%	0	0	
Phenol	0.03	0	0		0	0	
TCDD equivalents	420,000,000.00	6,533	0	0.0%	0	0	
Tetrachloroethene	0.07	0	0		0	0	
Toluene	0.01	2,688,007	895,635	33.3%	0	0	
Toxaphene	29,000.00	2,823	0	0.0%	0	0	
Total		33,587,944.8	10,289,055.8		7,295,760.3	1,974,540.2	
Toxic-Weighted Average				**30.63%**			**27.06%**

Source: Science Applications International Corporation and Jones and Stokes Associates, Incorporated, Analysis of Potential Costs Related to the Implementation of the Proposed California Water Quality Toxics Rule, prepared for the U.S. Environmental Protection Agency, November 1996

Exhibit 7-7

APPORTIONING USE AND NON-USE BENEFITS TO CONTROL OF POINT SOURCES

	Baseline Recreational Fishing		Baseline Non-Use Benefits		Point Source Contribution		Point Source Reduction		Potential Benefits Attributable to Implementing Point Source Controls		Potential Benefits Attributable to Control of Other Sources	
	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
San Francisco Bay	$4,278,000	$27,272,250	$2,139,000	$40,908,375	4%	11%	27%	31%	$69,304	$2,324,959	$6,347,696	$65,855,666
Other Bays and Estuaries	$14,257,882	$90,893,995	$7,128,941	$136,340,993	42%	64%	27%	31%	$2,425,266	$45,083,422	$18,961,557	$182,151,566
Rivers and Lakes*	$16,119,290	$77,737,311	$8,059,645	$116,605,967	5%	30%	27%	31%	$326,416	$18,073,925	$23,852,520	$176,269,353
TOTAL	$34,655,172	$195,903,556	$17,327,586	$293,855,334					$2,820,985	$65,482,306	$49,161,773	$424,276,585

* Includes saline lakes.

Sources: EPA analysis
Economic benefits analysis (see Chapter 4)

Other Bays and Estuaries

To estimate the economic benefits associated with point source control in bays and estuaries other than San Francisco Bay, we first need to refine our estimate of point source contributions to total toxics discharges. As shown earlier in Exhibit 7-3, available data suggest that urban bays are influenced more heavily by point sources than are non-urban bays. While point sources account for about 67 percent of toxics loadings to urban bays, they represent about 28 percent of toxic-weighted loadings to non-urban bays.[20] We developed two methods to obtain a combined measure of point source contributions to other bays. First, we develop an estimate scaling by population living around urban versus non-urban bays:

$$\frac{\textit{Population Near Urban Bays}}{\textit{Population Near All Bays}} * 67\% + \frac{\textit{Population Near Non-Urban Bays}}{\textit{Population Near All Bays}} * 28\%$$

This calculation implicitly assumes that the benefits we are apportioning to point sources (recreational fishing and non-use benefits) are proportional to the population living in different areas. For example, it assumes that more fishing occurs in urban bays than non-urban bays. While exceptions may exist, this generally will be true.

To estimate the population near urban and non-urban bays, we first identified the relevant set of enclosed bays covered by the rule. Urban bays include San Diego Bay, Mission Bay, Upper and Lower Newport Bay, and Los Angeles-Long Beach Harbor. Non-urban bays include Humboldt Bay, Bodega Harbor, Morro Bay, Drake's Estero, Tomales Bay, and Carmel Bay.[21] We obtained the total population living within 10 miles of each bay by aggregating census tract-level data (1990 Census) using geographic information system software. This method yields an estimate of approximately 3.1 million people living near urban bays and 275,000 people living near non-urban bays.

---

[20] The average urban bay figure represents the mean of the average point source contributions for the three "other" urban bays for which data were available, *as well as* San Francisco Bay. We added San Francisco Bay to this average because it is an urban bay for which available data suggest a lower point source contribution, offsetting the uncertainty associated with the NOAA data for the three other urban bays. The non-urban bay figure is simply the mean of the toxic-weighted average for Monterey and Humboldt Bay. In all cases, we use the median weight (100) for chlorinated pesticides in calculating the average across the different bays.

[21] The set of enclosed bays is taken from Water Resources Control Board, State of California, *California Enclosed Bays and Estuaries Plan*, April 1991.

Using the population-weighted approach, we estimate a weighted average point source contribution of about 64 percent for all bays other than San Francisco Bay.[22]

We can also scale urban and non-urban bays by their area rather than by the population living around them. Using information from the Water Quality Assessment data base, we compiled data on the total acreage of each of the urban and non-urban bays covered by the rule. Scaling by area yields an estimate of 42 percent of toxics loadings associated with point sources. We use this figure as the lower bound in developing the apportionment estimate.

Combining the range in estimated point source contributions (42 to 64 percent) with the range in point source control (27 to 31 percent) yields an estimate of $2 million to $45 million per year of economic benefits realized through control of point source discharges to other bays. These represent the majority of benefits to be realized through point source control, relative to the San Francisco Bay and freshwater estimates.

Freshwater

The benefits associated with control of point sources discharging to freshwater can be estimated by multiplying the baseline benefits by the point source contribution range estimated earlier in this chapter -- 5 to 30 percent. We then multiply by the point source reduction range (27 to 31 percent) to determine the benefits attributable to implementing point source control to meet the proposed water quality standards. As shown, this benefit ranges from a low of $300,000 to a high of $18 million.

APPORTIONMENT OF RECREATIONAL ANGLER HEALTH BENEFITS

EPA's health benefits assessment (presented in detail in Chapter 3) indicates that PCBs, dioxin, pesticides, and mercury account for the greatest share of cancer and noncancer risks to recreational anglers. A series of fish consumption health advisories in California waters demonstrates the potential risk posed by these four contaminants. For example, areas of Los Angeles Harbor (e.g., Belmont Pier and Cabrillo Pier) have fish consumption advisories for PCBs and pesticides, while San Francisco Bay has advisories posted for PCBs, pesticides, dioxin, and mercury. Additionally, regulators have issued consumption advisories for several ocean sites in southern California that are not included in the California Toxics Rule (e.g., Newport Pier, Redondo Pier, Malibu Pier, and Short Bank).

---

[22] [(3,100,000/3,379,000) * 67%] + [(275,000/3,379,000) * 28%] = 64 %

To derive apportioned angler health benefit estimates associated with reducing PCB, dioxin, mercury, and pesticide contaminant levels to meet water quality criteria, we examined existing literature and contacted experts to explore the extent to which these contaminants may be coming from point sources. Below, we discuss the results of our research. While the level of uncertainty in the available data precludes a quantitative estimate of risk reduction associated with point source control, we use the findings to roughly illustrate potential cancer and noncancer benefits.

Discussion of Information

PCBs

Production of PCBs, which began in 1929, was banned in the U.S. in 1979 because of concerns about toxicity, biomagnification, and environmental persistence. EPA estimates that more than 50 percent of all PCBs ever produced can be found in currently operating electrical transformers and capacitors. Point source PCB discharges can occur during the maintenance and disposal of electrical equipment, the overheating of transformers containing PCBs, leaks from industrial systems, and PCB waste disposal.[23]

Detection limits that are higher than effluent concentrations and water quality criteria pose the greatest obstacle to obtaining concrete data on point source discharges of PCBs. Limitations associated with current analytical techniques often prohibit the detection of PCBs in municipal and industrial effluent, even though these sources are suspected of discharging PCBs at concentrations greater than zero. In other words, since current analytical techniques can only measure water column concentrations that exceed the minimum detection limit (MDL) and water quality criteria fall below this level (i.e., 0 < water quality criteria < MDL), point source discharges that exceed water quality criteria may go unnoticed. EPA estimates a MDL of 0.065 micrograms per liter for most PCB compounds.

Point source discharges that exist, but can not be quantified using current analytical techniques, can be thought of as "hidden loads". EPA examined "hidden" PCB loadings from point sources as part of the Great Lakes Water Quality Guidance (1993).[24] Specifically, the report concluded that measured and "hidden" current point source loadings contributed between 0.02 and 1.28 percent of the concentration of PCBs in fish fillets. This evidence suggests that even if monitoring data do not explicitly link PCBs and point sources, discharges may still be significant.

---

[23] U.S. EPA, *Issues Related to the Cost-Effectiveness of Reducing PCB Inputs to the Great Lakes from Point Sources*, March 8, 1995.

[24] U.S. EPA, March 1995.

To further explore the question of whether point sources could be contributing to PCB discharges in California waters, EPA contacted informed personnel from the State Water Resources Control Board and various Regional Water Quality Control Boards, and other knowledgeable sources.[25] Most of those contacted had minimal knowledge of specific reports or data that directly link point sources to PCBs in California surface waters. Some staff members provided anecdotal information and suggested alternative leads for EPA to explore. These leads yielded three pieces of evidence indicating that a portion of PCB loadings may come from point sources.

> First, EPA consulted a Superfund database for sites affected by PCBs. Effluent from groundwater treatment at these sites may be discharged under a point source permit or to a point source permitted facility (e.g., local POTW). Some of the sites obtained from the database search include: Westinghouse Electric (Sunnyvale Plant), MGM Brakes (Cloverdale), and Lorentz Barrel & Drum (San Jose).
>
> Second, Permit Compliance System (PCS) data from 1990 to 1994 revealed that some POTWs observed PCB concentrations above detection limits, but below permit limits.
>
> Finally, upon review of the same PCS data, EPA discovered that some facilities without PCB limits had detected PCBs during routine monitoring. Some of the detected levels were significantly above the proposed water quality criterion and the MDL (i.e., greater than 0.065 micrograms per liter).

EPA also analyzed economic census data (1992) and PCS data for industries in the Great Lakes region reporting PCB discharges to see if any of these industries exist in California. For example, six nonmetallic mineral mining operations located in the Great Lakes region reported PCB discharges. Assuming that mining operations in the Great Lakes region and California use similar practices for mineral extraction, a portion of the 219 nonmetallic mining operations in California also may discharge PCBs. To test this claim, EPA examined PCS data for industries in California reporting PCB discharges. The results of this analysis indicate that of the 219 nonmetallic mining operations in California suspected of discharging PCBs, three reported actual discharges. Overall, many industries found to discharge PCBs to the Great Lakes are also present in California; these include lumber, furniture, printing, publishing, and chemical production. Appendix G provides a complete list that compares industries reporting PCB discharges in the Great Lakes region and the existence and number of similar industries in California.

---

[25] U.S. EPA, "PCB Data Search for California Toxics Rule (CTR)," memorandum from Erik Beck to California Toxics Rule File, October 17, 1996.

Finally, an EPA research initiative, the National Study of Chemical Residues in Fish, revealed potential point sources of PCBs and dioxin in California.[26] EPA established the study to determine the prevalence of selected bioaccumulative pollutants in fish. Scientists collected tissue samples of 119 different fish species from sampling sites across the U.S. thought to be influenced by a variety of point and nonpoint sources. This included tissue data taken from 26 sampling sites in California. More than half of the fish samples collected in California contained detectable levels of PCBs. Qualitative examination of site conditions determined that a portion of the contamination originated from point sources. Note that the qualitative examination of site conditions and the fish tissue analysis were conducted independently, thus we can not isolate the exact source of a particular pollutant. We list the 26 sampling sites and their associated contamination sources in Exhibit 7-8.

Dioxin

Similar to PCBs, dioxin is difficult to trace to point sources because of concentration levels that fall below detection limits. To obtain information on point source discharges of dioxin, EPA contacted a diverse group of knowledgeable personnel from the State Water Resources Control Board, Regional Water Quality Control Boards, and environmental non-profit organizations.[27]

Initial information gathered indicate that EPA Region IX currently has limited knowledge of dioxin discharges from current NPDES permitted paper or pulp mills. In addition, EPA Region IX has no evidence that any NPDES permitted POTWs were in violation of their dioxin discharge limits. As for industrial sources, a review of PCS data indicated that no facilities reported recent dioxin violations. Various conversations and data searches yielded a list of 45 facilities suspected of discharging dioxin to surface water currently or historically. Only two facilities on this list detected dioxin and had no discharge permit. However, no dioxin detection has occurred at either site since 1993. Once again, however, this lack of specific quantitative data may be attributable to dioxin concentration levels that fall below detection limits.

Subsequent investigations by EPA, however, did yield some information linking dioxin to point sources. Data from the Region 2 Water Quality Control Board indicate that several facilities around San Francisco Bay have recorded above-detect levels of dioxin in effluent. Additionally, stormwater data collected around San Francisco Bay indicate that dioxin congeners exist ubiquitously in area discharges.[28] The report concludes that if dioxin is measured in TEQs, all but two samples exceed the 0.013 pg/L level.

---

[26] U.S. EPA, *National Study of Chemical Residues in Fish*, Volumes I-II, Office of Science and Technology, September 1992.

[27] U.S. EPA, "Summary of Dioxin Data Search for California Toxics Rule (CTR) and Summary of Significant Findings," memorandum from Gary Sheth to California Toxics Rule File, October 18, 1996.

[28] California Regional Water Quality Control Board, *Survey of Storm Water Runoff for Dioxins in the San Francisco Bay Area*, February 1997.

Exhibit 7-8

POSSIBLE PCB AND DIOXIN DISCHARGE SOURCES AT SELECTED CALIFORNIA SAMPLE SITES

Episode #	Waterbody	Location	Point Sources							Nonpoint Sources		Pollutant Detected	
			Paper/Pulp Mill Using Chlorine	Paper/Pulp Mill Not Using Chlorine	Refinery	Superfund Site	Other Industrial Discharge	POTW	Wood Preserving Activity	Urban Runoff	Agricultural Runoff	PCBs	Dioxin
3282	Alamo River	Calipatria									X	✓	✓
3288	Blanco Drain	Salinas					X				X	✓	✓
3285	Colorado Lagoon	Long Beach					X			X		✓	✓
3273	Elk Creek	Crescent City							X			✓	✓
3286	Harbor Park Lake	Harbor City					X			X		✓	✓
3271	Hayfork Creek	Hayfork							X				✓
3272	Lauritzen Canal	Richmond				X						✓	✓
3275	Mad River	Arcata					X						
3276	Mad River Slough	Arcata					X					✓	✓
3289	Moss Landing Dam	Moss Landing					X					✓	✓
3451	Mouth of Malibu Creek	Malibu						X					✓
3354	New Mormon Slough	Stockton				X	X			X	X	✓	✓

Exhibit 7-8

POSSIBLE PCB AND DIOXIN DISCHARGE SOURCES AT SELECTED CALIFORNIA SAMPLE SITES

Episode #	Waterbody	Location	Point Sources							Nonpoint Sources		Pollutant Detected	
			Paper/Pulp Mill Using Chlorine	Paper/Pulp Mill Not Using Chlorine	Refinery	Superfund Site	Other Industrial Discharge	POTW	Wood Preserving Activity	Urban Runoff	Agricultural Runoff	PCBs	Dioxin
3283	New River	Westmore-land					X					✓	✓
3355	Old Mormon Slough	Stockton				X	X			X	X	✓	✓
3290	Port of Stockton	Stockton				X	X					✓	✓
3274	Rowdy Creek	Smith River							X			✓	✓
3357	Sacramento Delta	Antioch	X				X				X	✓	✓
3267	Sacramento River	Anderson	X									✓	✓
3270	Sacramento River	Red Bluff		X							X	✓	✓
3287	San Gabriel River	Long Beach		X								✓	✓
2748	Santa Clara River	Santa Paula											
3281	Santa Clara River	Santa Paula										✓	✓

Exhibit 7-8

POSSIBLE PCB AND DIOXIN DISCHARGE SOURCES AT SELECTED CALIFORNIA SAMPLE SITES

Episode #	Waterbody	Location	Point Sources							Nonpoint Sources		Pollutant Detected	
			Paper/Pulp Mill Using Chlorine	Paper/Pulp Mill Not Using Chlorine	Refinery	Superfund Site	Other Industrial Discharge	POTW	Wood Preserving Activity	Urban Runoff	Agricultural Runoff	PCBs	Dioxin
3264	Santa Monica Bay	Los Angeles			X		X	X		X			✓
3450	Short Bank	Los Angeles						X					✓
3269	Stanislaus River	Ripon					X						✓
3278	Upper Eel River	Potter Valley							X			✓	✓

Source: U.S. EPA, *National Study of Chemical Residues in Fish*, Volumes I-II, Office of Science and Technology, September 1992.

In addition, a study developed for EPA found that sludge samples taken from 175 POTWs across the U.S. all contained detectable levels of at least one dioxin congener.[29] The presence of dioxin in sludges suggests that small amounts of dioxin may be present in effluent, although these discharges may occur at concentrations below detection. Other studies trace the dioxin found in household wastewater and POTW sludge to fabric dyes.[30] These studies suggest that clothing containing dioxin-contaminated dyes, when washed in household washing machines, may be a potential source of dioxins to POTWS serving primarily residential populations. The authors also hypothesized an additional source of dioxins to POTWs via the use of pentachlorphenol (PCP) to preserve cotton, particularly when it is randomly strewn on bales of cotton as a preservative during sea transport.[31]

Finally, the EPA national fish tissue study mentioned for PCBs (see above) also examined dioxin contamination. Specifically, more than half of the fish samples collected contained detectable levels of dioxin that could negatively affect human health. A qualitative evaluation of discharges in the area suggests that point sources may be a significant contributor (see Exhibit 7-8).

Mercury

Mercury poses significant noncancer risk to recreational anglers in California. As reviewed in Chapter 3, mercury hazard quotients greater than 1 are possible under typical consumption assumptions for both freshwater and San Francisco Bay anglers. While data are sparse, it is likely that a significant share of mercury originates from point sources. The Davis and NOAA data for San Francisco Bay suggest that point sources may contribute between 26 and 52 percent of mercury loadings.[32] In addition, mine drainage to freshwater such as the Sacramento River is a major source of mercury loadings, although data are not available to assess the specific magnitude of this contribution.

---

[29]Rubin, A. and White, C., Work conducted for the U.S. EPA, Office of Science and Technology, Health and Ecological Criteria Division, Sludge Risk Assessment Branch, December 21, 1992.

[30] Hoistman and McLachlan in U.S. EPA, *Estimating Exposure to Dioxin-Like Compounds*, Vol. III, June 1988, (EPA/600/6-88/005Ca,b,c).

[31]While PCP for nonwood uses has been banned in the U.S. since 1987, it is still used in other countries, especially for the purpose of preserving cotton during sea transport.

[32] Davis, J.A., et al., *Status and Trends Report on Pollutants in the San Francisco Estuary*, prepared by the San Francisco Bay-Delta Aquatic Habitat Institute for the San Francisco Estuary Project, U.S. EPA, March 1991.

Pesticides

Our analysis in Chapter 3 also demonstrates that pesticides pose significant risks -- both cancer and noncancer -- to recreational anglers. Overall, pesticides account for 63 percent of total cancer cases in freshwater and 51 percent of total cancer cases for San Francisco Bay. In addition, pesticides contribute significantly to the overall hazard index for noncancer risks.

The NOAA data suggest that point sources account for about half of the pesticide discharges to San Francisco Bay. Data for inland waters are not readily available. Many pesticide loadings originate from household waste disposal, accidental industrial releases, and the expansion of cities into land formerly used for farming. In the case of DDT, whose production is banned in the U.S., potential sources include historic sludge residuals in sewers, the chemical breakdown of currently manufactured pesticides, and possible illegal importation from outside the U.S.[33] This complex "cycling" of pesticides in the environment makes it difficult to accurately divide pesticide releases between point and nonpoint sources.

Illustrative Calculation of Benefits
Attributable to Point Source Control

While none of the data sources mentioned above definitively estimates the relative point source contribution of PCBs, dioxin, pesticides, or mercury, they collectively support the argument that at least a portion of these pollutants may be discharged by point sources. Point source controls potentially could lead to reductions in both cancer and noncancer health risks. To estimate potential benefits in terms of averted cancer cases, we perform the following calculation:

Point Source Contribution (Percent)	*	Point Source Reduction (Percent)	*	Cancer Cases Per Year	=	Cancer Cases Averted

For illustrative purposes, we assume that point sources contribute a relatively small percentage (five percent) of the total toxic loadings of PCBs and dioxin to surface waters in California. We base this assumption on the limited knowledge of the sources of these constituents, as discussed above. Further, we assume that when the proposed water quality criteria are fully implemented by the State through the NPDES point source discharge program, a small (five percent) point source load reduction will occur. We can take this calculation one step further by multiplying the number of cancer cases averted by the statistical value of a human life ($2 to $10 million).

[33] Personal Communications with Phil Woods and Terry Oda, U.S. EPA, Region IX, San Francisco, California, December 1996.

Potential cancer health benefits for point source controls of PCBs are presented in Exhibit 7-9. The results of our analysis indicate that if implementation of the proposed rule leads to a five percent loadings reduction of PCBs discharged from point sources to freshwater, then we can expect an upper bound benefit of $100,000 per year.

We can use essentially the same calculation to estimate the reduction in the hazard quotient for noncancer risks. As shown in Exhibit 7-10, the potential reduction in noncancer risks is minor for most pollutants. For example, if the proposed rule leads to a five percent loadings reduction for PCBs discharged from point sources along San Francisco Bay, then we can expect an upper bound noncancer hazard quotient reduction of 0.008.

As shown in Exhibit 7-10, there is a potential reduction in the hazard quotient for freshwater mercury. For the point source contribution figure, we use the toxics-weighted average (46 percent) of several metals discharged to the Sacramento River (the CVRWQCB data from Exhibit 7-4). For the discharge reduction percent, we use the upper bound figure from the cost analysis (71 percent). Under these assumptions, the upper bound hazard quotient would be reduced from 1.44 to 0.97.

Conclusions

Overall, the inability to detect small but potentially harmful concentrations of PCBs and dioxin limits our ability to definitively link these pollutants to point source dischargers. Nonetheless, some evidence exists to suggest that point sources contribute to overall releases of these pollutants. However, even if we assume that point sources are responsible for five percent of discharges and will reduce these discharges by five percent, the cancer and noncancer benefits are limited. For example, monetized cancer reduction benefits for PCBs might approach $100,000 per year in the upper bound based on simple illustrative calculations.

For mercury and pesticides, the link to point sources is somewhat more established. This is especially true in the case of mercury, for which mines are associated with a large share of discharges. Preliminary estimates suggest that the noncancer hazard quotient for mercury could be reduced from hazardous levels (HQ > 1) to non-hazardous levels (HQ < 1) if the predicted point source mercury reductions presented in the costing analysis are achieved.

APPORTIONMENT OF ECOLOGICAL BENEFITS

The analysis of point source contributions to total toxics loadings can be used to approximate very generally the portion of ecological benefits attributable to point source controls. Because California waters and the ecosystems they support are extensive and diverse, it is difficult to make

Exhibit 7-9

POTENTIAL CANCER RISK BENEFITS ASSOCIATED WITH POINT SOURCE CONTROLS ACHIEVED THROUGH IMPLEMENTATION OF THE CALIFORNIA TOXICS RULE

Pollutant	Point Source Contribution	Point Source Reduction	Population Cancer Risk (excess cases per year)		Number of Excess Cancer Cases Averted		Statistical Value of a Human Life		Annual Benefits Attributable to Point Source Control	
			Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
PCBs (Freshwater)	5%	5%	2	4	0.005	0.01	$2M	$10M	$10,000	$100,000

Exhibit 7-10

POTENTIAL NONCANCER RISK BENEFITS ASSOCIATED WITH POINT SOURCE CONTROLS ACHIEVED THROUGH IMPLEMENTATION OF THE CALIFORNIA TOXICS RULE

Pollutant	Point Source Contribution	Point Source Reduction	Hazard Quotient from Typical Consumption (21.4 - 49.6 g/day)		Reduction in Hazard Quotient from Point Source Control	
			Lower Bound	Upper Bound	Lower Bound	Upper Bound
PCBs (Freshwater)	5%	5%	1.40	3.30	0.004	0.008
PCBs (San Francisco)	5%	5%	2.26	5.24	0.006	0.013
Dioxin (San Francisco)	5%	5%	0.51	1.17	0.001	0.003
Mercury (Freshwater)	46%[1]	71%[2]	0.62	1.44	0.204	0.474

Notes: 1) The 46.34 percent figure can be found in Exhibit 7-4. This figure represents the toxic-weighted average point source contribution to freshwater for several metals other than mercury; mercury data are not available.
2) The 71.1 percent figure can be found in Exhibit 7-6 and reflects the upper bound point source reduction estimate.

state-wide generalizations about the relative toxic discharge contribution of point and nonpoint sources to all water bodies in the State. Consequently, we apply information developed for San Francisco Bay, other enclosed bays and estuaries, and freshwater (as described earlier in this chapter) to apportion ecological benefits for the entire State. Like the economic assessment, it is not possible to allocate ecological benefits on a pollutant-specific basis because of data, methodological, and time constraints. Therefore, we develop a very rough, quantitative apportionment analysis that uses average point source contributions and loadings reductions across all pollutants, similar to that described in the previous economic apportionment section.

First, we use the quantitative measure of miles of rivers, or acres of lakes, bays, harbors, estuaries, and wetlands that may be adversely affected by toxics and whose beneficial use includes waters supporting rare or endangered species; supporting wildlife; or supporting fish spawning and/or migration. Exhibit 7-11 summarizes the total baseline toxics-affected acreage for California waters, disaggregated by type of waterbody and beneficial use, based on information described and presented in Chapter 5.

Next, we multiply this area estimate by a relevant point source contribution range. This provides a very rough estimate of the benefits that would be realized if all point source discharges of pollutants were reduced to meet CTR criteria. The point source contributions we apply are developed from information presented earlier in this chapter. For rivers and streams and lakes and reservoirs, we use the same range of five to 30 percent used in the economic analysis. For San Francisco Bay, we have applied a slightly higher single estimate of point source contribution (15 percent) consistent with the upper range of the NOAA and Davis studies of San Francisco Bay. We do so because silver is not included as a constituent in these latter studies, although other studies have demonstrated that silver in San Francisco Bay is primarily attributable to industrial wastewater discharges.[34] Further, silver is more toxic to aquatic life than all the other metals except for mercury, and has the highest baseline loadings and one of the highest upper bound percent reductions (51 percent) of any of the other constituents considered in the NOAA/Davis data (see Exhibit 7-6). For these reasons, we assume that the point source contribution to San Francisco Bay is slightly higher than that developed for the economic analysis. It is possible that the point source contribution in some parts of the Bay could be even higher than 15 percent, although data and time limitations precluded a more detailed assessment and conclusion.

For point source contributions of other inland bays, and wetlands, we have applied the range of 87 to 91 percent reported in NOAA for Urban Bays, and for estuaries we have applied the 23 to 33 percent reported for non-urban bays (see Exhibit 7-3). We have not adjusted these estimates by population figures (as we did in the economic application) because the ecological benefits are not

---

[34] Smith, Geoffrey, and A. Russell Flegal, "Silver in San Francisco Bay Estuarine Waters," *Estuaries*, Vol. 16, No. 3A, September 1993, pp. 547-558.

dependant on any population measure of activity. For saline lakes, the point source contribution of toxics is estimated to be zero given the generally accepted dominance of agricultural runoff influencing the Salton Sea.

Finally, we multiply by the average percentage reduction in point source loadings as estimated in the cost analysis and used in both the economic and human health apportionment to derive an estimate of ecological benefits attributable to expected point source controls.

The results of this screening analysis are shown in Exhibit 7-11. Average point source benefits range from a low of zero percent improvement in saline lakes, to a potential 25 percent improvement in other inland bays. Approximately 20,000 acres of bays, harbors, estuaries, lakes, and wetlands and nearly 150 miles of rivers may experience improved conditions as a result of point source controls. These areas support wildlife, rare or endangered species, or fish spawning and/or migration.

UNCERTAINTIES AND LIMITATIONS

As discussed throughout the chapter, the apportionment methodology has a number of uncertainties and limitations. Exhibit 7-12 summarizes these uncertainties and highlights several that are likely to be of greatest significance.

Most importantly, the estimates presented here do not make direct causal links between point source controls and the stated benefits (e.g., improved recreational fishing, reduced health risk). Instead, the method is based on an accounting of recent loadings to various waterbodies and assumes that benefits accrue in proportion to these loadings (i.e., reducing loadings will reduce the damages linearly). A number of factors may preclude this outcome. For example, fish tissue concentrations may be the result of toxics in sediments that move through the food chain to fish and humans. Reduction of point source loadings to meet water quality standards may do little in the near term to reduce the effects of this kind of historical pollution. Similarly, recovery of a stressed ecosystem or species may be subject to a threshold effect. For instance, reduction of toxics loadings by 20 percent may have no effect if a particularly sensitive species requires complete elimination of a given contaminant. Conversely, a small reduction in loadings may be all that is need for a full recovery of a species or ecosystem.

Exhibit 7-11

APPORTIONING ECOLOGICAL BENEFITS TO CONTROL OF POINT SOURCES

					Potential Benefits Attributable to Control of Point Sources	**Potential Benefits Attributable to Control of Nonpoint Sources**
Area	Total Baseline Waters Affected Supporting: (a) Rare or Endangered Species (b) Wildlife (c) Fish spawning and/or Migration (1)	Point Source Contribution (2)	Point Source Reduction (3)	Average Point source Benefits	Waters Supporting: (a) Rare or Endangered Species (b) Wildlife (c) Fish spawning and/or Migration	Waters Supporting: (a) Rare or Endangered Species (b) Wildlife (c) Fish spawning and/or Migration
San Francisco Bay (Acres)	(a) 172,500 (b) 172,500 (c) 172,500	15%	27 - 31%	5%	(a) 8,625 (b) 8,625 (c) 8,625	(a) 163,875 (b) 163,875 (c) 163,875
Other Inland Bays (Acres)	(a) 3,679 (b) 3,240 (c) 2,625	87-91%	27 - 31%	25%	(a) 920 (b) 810 (c) 656	(a) 2,759 (b) 2,430 (c) 1,969
Estuaries (Acres)	(a) 5,116 (b) 51,869 (c) 51,656	23 - 33%	27 - 31%	8%	(a) 420 (b) 4,253 (c) 4,236	(a) 4,696 (b) 47,616 (c) 47,420
Lakes & Reservoirs (Acres)	(a) 33,390 (b) 107,231 (c) 102,241	5 - 30%	27 - 31%	5%	(a) 1,720 (b) 5,522 (c) 5,255	(a) 31,670 (b) 101,709 (c) 96,986
Saline Lakes (Acres)	(a) 230,855 (b) 286,182 (c) 10,855	0%	27 - 31%	0%	(a) 0 (b) 0 (c) 0	(a) 230,855 (b) 286,182 (c) 10,855
Rivers & Streams (Miles)	(a) 1,856 (b) 2,591 (c) 1,029	5 - 30%	27 - 31%	5%	(a) 96 (b) 133 (c) 53	(a) 1,760 (b) 2,458 (c) 976
Wetlands (Acres)	(a) 225 (b) 385 (c) 225	23 - 33%	27 - 31%	8%	(a) 18 (b) 32 (c) 18	(a) 207 (b) 353 (c) 207

(1) Source: Exhibit 5-4, based on WQA data base.
(2) Source: Exhibits 7-1, 7-2, 7-3, 7-4, 7-5, and 7-6.
(3) Source: Exhibit 7-6.

Exhibit 7-12

UNCERTAINTIES AND LIMITATIONS IN THE APPORTIONMENT ANALYSIS

Description of Uncertainty	Relative Significance	Nature and Direction of Bias in Point Source Control Benefit Estimates		
		Overstate Estimates	Understate Estimates	Not Clear
Assume direct proportionality between economic/health benefits and point source controls.	High			✓
Generalize from limited loadings data for a small set of water bodies to the extensive system of salt and freshwater in California.	High			✓
Uncertainties associated with the 1994 California Water Quality Assessment data base to characterize the quality of California surface waters.	High			✓
Analysis based on a limited set of pollutants. Little information on pesticides, PCBs, dioxin, and certain metals (e.g., silver).	High		✓	
Detection limits for some key pollutants (e.g., PCBs and dioxin) too high to estimate reliably the relative contribution of point and other sources.	High		✓	
Assume reduced loadings of toxics from point source discharges from active, inactive, and abandoned mines occurs in the same time frame as other point source controls.	High	✓		
Data for San Francisco Bay do not include many sources, such as mine drainage. NOAA lacks several nonpoint sources.	Medium	✓		
While riverine inputs are classified as a nonpoint source, discharges to these rivers may have originated from either point or nonpoint sources.	Medium		✓	

Exhibit 7-12

UNCERTAINTIES AND LIMITATIONS IN THE APPORTIONMENT ANALYSIS

Description of Uncertainty	Relative Significance	Nature and Direction of Bias in Point Source Control Benefit Estimates		
		Overstate Estimates	Understate Estimates	Not Clear
Davis did not include loadings estimates for the Sacramento River.	Medium	✓		
Point source contributions for San Francisco Bay are much lower than for the other urban bays.	Medium			✓
CVRWQCB data for freshwater consider urban runoff at only a limited subset of cities.	Medium	✓		
CVRWQCB data for San Joaquin River include only one mine.	Medium		✓	
NOAA and Davis data are based on discharges from the early and mid-1980s.	Low			✓
Davis used national runoff pollutant concentrations to estimate loadings from urban runoff.	Low			✓
Davis' atmospheric deposition estimates are based on deposition rates from other parts of the country.	Low			✓
CVRWQCB data use effluent concentrations from only one POTW.	Low			✓

A second key limitation already mentioned above is the need to generalize from very limited loadings data to all waters in California. Except in the case of San Francisco Bay, we assume that large, complex waterbodies have a discharge profile like the example for which we have data; for example, we assume that other rivers are similar to the Sacramento and San Joaquin for which we have data. Unique local conditions make it likely that certain areas and waterbodies will be poorly represented by the available data. While a more detailed analysis of point source and other discharges in key waterbodies would be desirable, such an analysis is beyond the scope of this effort.

Third, we analyze a relatively limited set of pollutants. Available data focus primarily on several metals. While these are important pollutants from the standpoint of ecological risk, they may not fully represent benefits and the likely impact of point source controls. Silver provides a good illustration of this uncertainty. Studies have demonstrated that silver in San Francisco Bay is primarily attributable to industrial wastewater discharges.[35] In addition, silver has a high toxicity weight (47), suggesting that it would strongly influence the calculation of average point source contributions for San Francisco Bay. Nonetheless, complete data on discharges of silver from point and nonpoint sources were not available. In this case, the likely result is that we understate point source contributions. For other pollutants missing from the analysis, nonpoint sources may dominate and lead us to overstate point source contributions.

Fourth, while mines are considered to be a point source subject to NPDES under the Clean Water Act, not all mines in California have been permitted. Loadings reductions for mines (both active and inactive) with major NPDES permits have been estimated, and are used in this analysis, although they do not represent the entire universe of mines in the State. Consequently, some of the benefits estimated in this chapter, particularly those based on the control of mercury, may not occur in the same time frame as benefits associated with other point sources evaluated here (POTWs and industrial dischargers). The likely result is an overstatement of some of the benefits associated with point sources, although it is not possible to evaluate the magnitude of the bias.

Finally, one key reason for analyzing a relatively limited set of pollutants is the problem of detection limits. Pollutants such as dioxin and PCBs play a significant role in the health risk analysis; however, apportionment of these benefits is impeded by the inability to detect certain pollutants, even in concentrations exceeding the criteria. When pollutants cannot be detected, it becomes impossible to characterize the relative importance of point sources and other sources.

---

[35] Smith, Geoffrey, and A. Russell Flegal, "Silver in San Francisco Bay Estuarine Waters," *Estuaries*, Vol. 16, No. 3A, September 1993, pp. 547-558.

REFERENCES

Beck, E., U.S. EPA, "PCB Data Search for California Toxics Rule (CTR)," memorandum to California Toxics Rule File, October 17, 1996

California Regional Water Quality Control Board, San Francisco Bay Region, *Survey of Storm Water Runoff for Dioxins in the San Francisco Bay Area*, February 1997.

California Regional Water Quality Control Board, Central Valley Region, *Inactive Mine Drainage in the Sacramento Valley, California*, 1992.

California Regional Water Quality Control Board, Central Valley Region, *A Mass Loading Assessment of Major Point and Nonpoint Sources Discharging to Surface Waters in the Central Valley, California, 1985*, Draft Staff Report, October, 1988.

Central Valley Regional Water Quality Control Board, *Mass Emission Strategy Load Estimates*, internal staff report, no date.

Davis, J.A., et al., *Status and Trends Report on Pollutants in the San Francisco Estuary*, prepared by the San Francisco Bay-Delta Aquatic Habitat Institute for the San Francisco Estuary Project, U.S. EPA, March 1991.

Gunther, A.J., et al., *An Assessment of the Loading of Toxic Contaminants to the San Francisco Bay-Delta*, prepared by the Aquatic Habitat Institute, 1987.

NOAA, *The National Coastal Pollutant Discharge Inventory: Estimates for San Francisco Bay, Data Summary*, Ocean Assessments Division, National Oceanic and Atmospheric Administration, June 1988.

Rubin, A. and White, C., Work conducted for the U.S. EPA, Office of Science and Technology, Health and Ecological Criteria Division, Sludge Risk Assessment Branch, December 21, 1992.

SAIC, *Assessment of Compliance Costs Resulting from Implementation of the Final Great Lakes Water Quality Guidance*, prepared for the U.S. Environmental Protection Agency, March 13, 1995.

SAIC, *Analysis of Potential Costs Related to the Implementation of the California Toxics Rule*, Final Draft, prepared for the U.S. Environmental Protection Agency, May 1997.

Sheth, G., U.S. EPA, "Summary of Dioxin Data Search for California Toxics Rule (CTR) and Summary of Significant Findings," memorandum to California Toxics Rule File, October 18, 1996.

Smith, Geoffrey, and A. Russell Flegal, "Silver in San Francisco Bay Estuarine Waters," *Estuaries*, Vol. 16, No. 3A, September 1993, pp. 547-558.

U.S. EPA, *Estimating Exposure to Dioxin-Like Compounds*, Volume III, June 1988, (EPA/600/6-88/005Ca,b,c).

U.S. EPA, *Issues Related to the Cost-Effectiveness of Reducing PCB Inputs to the Great Lakes from Point Sources*, March 8, 1995.

U.S. EPA, *National Study of Chemical Residues in Fish*, Volumes I-II, Office of Science and Technology, September 1992.

Water Resources Control Board, State of California, *California Enclosed Bays and Estuaries Plan*, April 1991.